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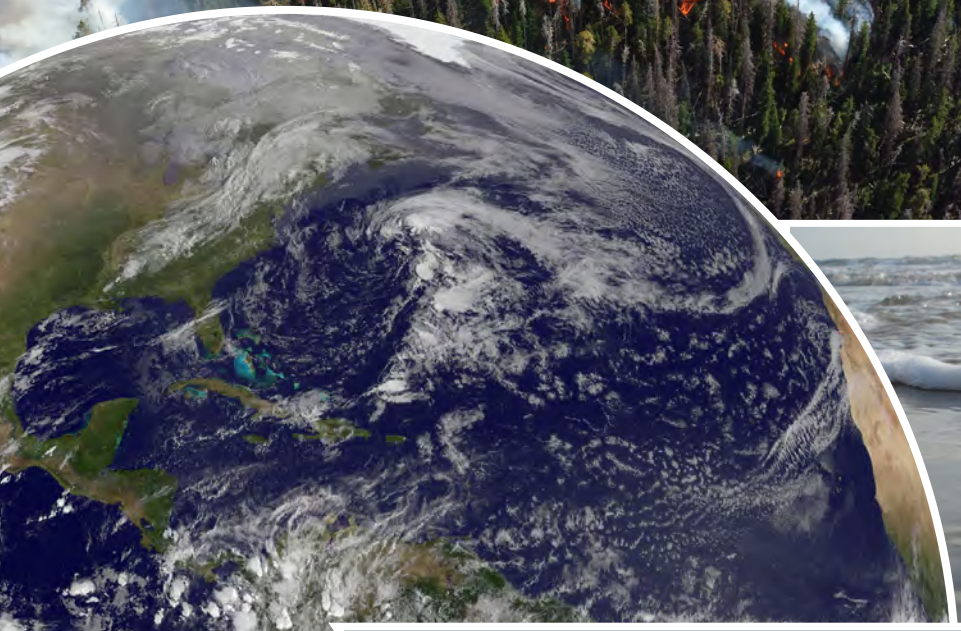
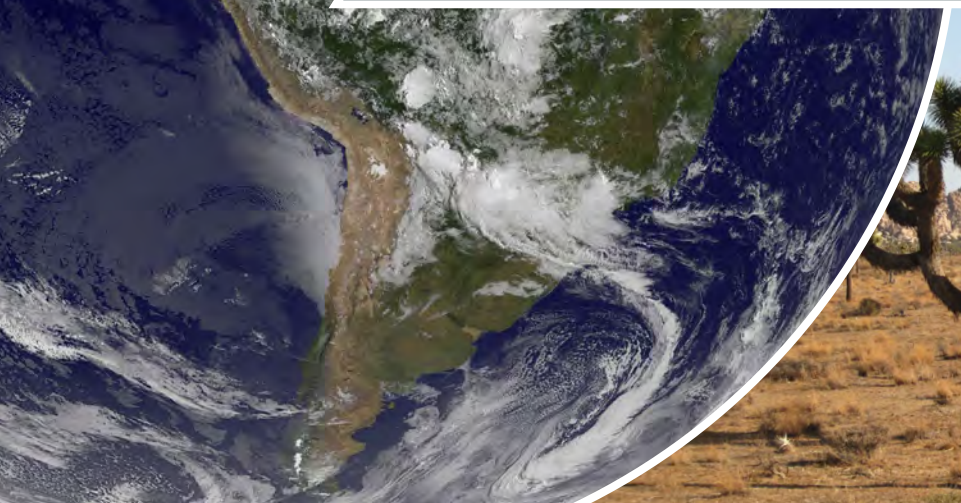


Planning for a Changing Climate

Climate-Smart Planning and Management in the National Park Service



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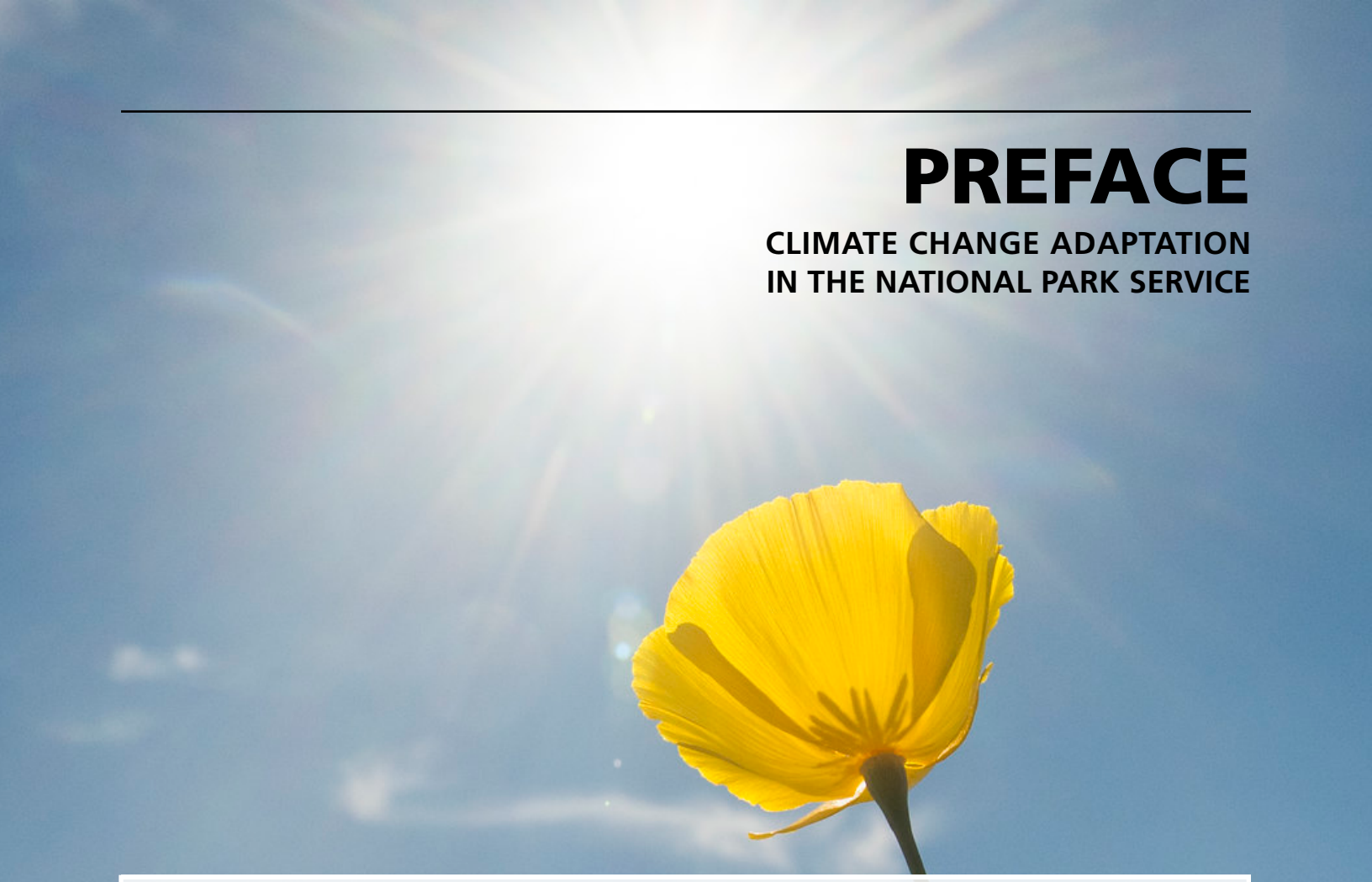
PREFACE

CLIMATE CHANGE ADAPTATION IN THE NATIONAL PARK SERVICE



MEETING THE CHALLENGE

In the National Park Service's (NPS) second century, park managers face new challenges unimagined even a few years ago. As environmental change accelerates, proactive and deliberate planning for unprecedented, but plausible, future conditions must now augment managerial skills in park administration, resource protection and conservation, visitor use, interpretation, facilities, concessions, and community and civic engagement.

Planning for a Changing Climate guides NPS planners and managers in developing robust climate change adaptation strategies to better protect park resources and assets today and for future generations. The guide derives from *Climate-Smart Conservation*, the product of an interagency and nongovernmental organization partnership led by the National Wildlife Federation (NWF). *Planning for a Changing Climate* incorporates scenario planning concepts in the climate-smart framework to advance adaptation planning in the National Park Service.

Numerous contributors assisted in preparation of Version 1.0 of this guide. First and foremost, the National Park Service sincerely thanks Patty Glick and Bruce Stein (National Wildlife Federation) who were lead authors in this effort, and Jonathan Star (Scenario Insight) who contributed content and fundamental guidance on scenario planning principles. NPS co-authors were John Gross, Cat Hawkins Hoffman, David Lawrence, Gregor Schuurman, and Don Wojcik. Larry Perez, Wylie Carr, and Matt Holly assisted in document formatting, graphics, and editing.

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SECTION ONE

INTRODUCTION AND BACKGROUND

Introduction

Over the past century, the National Park Service (NPS) steadfastly worked to sustain America's natural and cultural heritage, preserving and protecting special places and providing visitors with opportunities to experience and understand these priceless resources and values. In addition to numerous challenges already confronting national parks, the NPS now faces the broad-scale threat of a rapidly changing climate, which has the potential to dramatically affect natural and cultural resources under our stewardship. Addressing climate change in the full range of NPS planning efforts is integral to the agency's ability to meet its mission under conditions of rapid environmental change.

Effects of rising temperatures, altered precipitation patterns, stronger storms, and other climatic changes are already evident in America's national parks. These include more severe wildland fires and floods, declining snowpack, melting glaciers, rising sea levels, more frequent coastal inundation, and increased erosion [1, 2, 3, 4].

Such changes can alter ecosystems and disrupt wildlife; threaten cultural and historic resources; damage buildings, roads, and other infrastructure; and affect visitor experiences and behaviors. Additionally, climate change can magnify the impacts of invasive species, pollution, and many other environmental concerns affecting national parks and their surrounding communities.

The National Park Service recognizes the importance of addressing the effects of current and future climate change in its planning and operations, an approach known as ***climate adaptation***[1] [5]. Defined as "the process of adjustment to actual or expected climate and its effects" [6], adaptation is a form of risk management that seeks to reduce climate-related vulnerabilities or take advantage of potential benefits. The scope, pace, and magnitude of climate-related changes will continue to present new challenges for the National Park Service, with an accompanying reality that it will not be possible to safeguard all park resources, processes, assets, and values in their current form or context over the long term.

1 **A Note about Terminology.** Although most users of this guide will have extensive knowledge and understanding of planning concepts and terminology, usage of certain terms varies across disciplines and communities of practice, even within the National Park Service. Acknowledging these differences, the glossary defines specific terms used throughout the guide to clarify the meaning in the context of this publication. Terms included in the glossary are highlighted in ***bold green italics*** in the main text.

Routinely incorporating climate adaptation into NPS planning will best prepare the agency to manage for continuous and uncertain changes to come. Within this context, NPS managers will need to consider when and where it may be possible and strategic to *resist* undesirable changes, when it may be prudent to *accept* changing conditions, and when it may be appropriate to actively *direct* change in valued systems and resources (see Table 1).

Purpose of This Guide

The purpose of this guide is to help NPS planners and managers identify climate adaptation options as a regular practice across comprehensive, strategic, and implementation plans (e.g. general management plans, resource stewardship strategies, long-range transportation plans, visitor use management plans, cultural landscape reports, historic structure reports and development concept plans). The guide offers a general adaptation planning framework that is flexible to meet a wide range of planning and management needs. It builds on an existing adaptation planning approach developed by an interagency team that included the National Park Service, as described in *Climate-Smart Conservation: Putting Adaptation Principles into Practice* [7], and tailors that approach to better reflect and address the full spectrum of NPS stewardship responsibilities.

The guide assumes the reader is familiar with basic NPS planning concepts, processes, and requirements. Because it presents a general adaptation framework for NPS application, the guide does not offer specific guidance on NPS compliance with particular statutes or regulations. Guidance for compliance with laws such as the National Environmental Protection Act (NEPA), National Historic Preservation Act, Wilderness Act, and Endangered Species Act is available through various Director's Orders and manuals [8, 9, 10, 11, 12, 13].

A Note About Planning for Adaptation

Developing climate change adaptation strategies as part of NPS planning documents requires consideration of climate projections and other types of information that may be new to traditional planning processes. Including this information is best done at the outset of planning, not as an "add-on" after planning is underway. Whether accomplished through contracts or by planning specialists in parks, regions, or the Denver Service Center, it is important to consider the need to include climate change-related information as part of the planning process design, costs, and scheduling.[2]

Is Climate Change Relevant?

Some planners ask whether "all" plans must consider climate change. The answer is "yes"—*considering* climate change vulnerabilities is a relevant part of all planning processes. That is, asking whether climate change affects the ability to meet planning goals or objectives is pertinent to all planning processes. The answer may sometimes be "no"—for example in plans for short term, minimal investment, or easily modified/reversed outcomes—but it's important to ask the question.

Integrate Adaptation into Existing Planning and Management

Climate adaptation does not require a *separate* planning endeavor or a stand-alone plan. Instead, one of the best ways to address climate change is through "mainstreaming" adaptation as a routine component of planning tools and processes. Climate adaptation is context-specific, and there is no single "right" approach. This guide emphasizes fundamental principles and a general framework to support any NPS planning need.

2 Planners may contact staff of the NPS Climate Change Response Program (CCRP) or submit a request through the NPS Solutions through Technical Assistance Requests (STAR program) for assistance in scoping climate change information needs and sources.

Climate Adaptation and the National Park Service

In 2016, the National Park Service began its second century of preserving America's natural and cultural heritage, now including more than 400 park units, over 84 million acres, and thousands of infrastructure assets. As scientific knowledge grew over its first 100 years, enormous evolution occurred in NPS management policies and practices to meet the overarching goal of the agency under the NPS Organic Act[3] [14]. The National Park Service's second century of management—continually informed by science—will see equally dramatic changes in goals and practices to protect these special places. Working to understand how climate change affects park resources and infrastructure is part of our core responsibility to protect parks. In the context of the NPS's long history of protecting national park land, climate adaptation is not a radical departure from tradition, but represents an evolution in the agency's work to address new types of impacts. Nonetheless, climate adaptation requires special attention as the scope and magnitude of climate change effects present challenges that are fundamentally different than most previous environmental problems. At its core, the purpose of adaptation is to reduce the vulnerabilities of, and minimize risks to, park values (resources, assets, experiences) from climate change. Addressing climate change as a routine component of park planning and decision making is the portal to adaptation.

The NPS ***Climate Change Response Strategy*** notes that adaptation pertains to virtually all NPS operations [5]. This guide helps to implement the following goals of the *Strategy*.

1. **Engage in adaptation planning:** incorporate climate change considerations and responses in all levels of NPS planning, including ***scenario planning*** to explore the range of potential conditions that parks may experience, and possible consequences associated with particular actions.

2. **Promote ecosystem resilience:** implement adaptation strategies that promote ecosystem resilience and enhance restoration, conservation, and preservation of park resources.

3. **Preserve cultural heritage:** develop, prioritize, and implement management strategies to preserve climate-sensitive cultural resources.

4. **Protect facilities and infrastructure:** enhance the sustainable design, construction, and maintenance of park infrastructure.

3 "[T]o conserve the scenery and the natural and historic objects and the wild life therein, and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations".

Fundamentals of National Park Service Adaptation Planning and Management

Several characteristics distinguish climate-informed plans. First, adaptation planning necessarily requires that park planners and managers examine climate projections for their area and actively consider a range of ***plausible future conditions***, some of which may significantly differ from those of today. Fundamentally, NPS planning processes need to:

- *Develop forward-looking goals* that consider future climatic conditions.
- *Consider more than one scenario* of the future when developing management strategies and actions.

Additionally, during the planning process, purposeful application of the following principles further distinguishes climate-informed planning from "business as usual" [7]:

- Act with ***intentionality***; link actions to climate impacts.
- Manage for change, not just persistence.
- Reconsider existing management goals, not just strategies and actions.

Develop Forward-Looking Goals

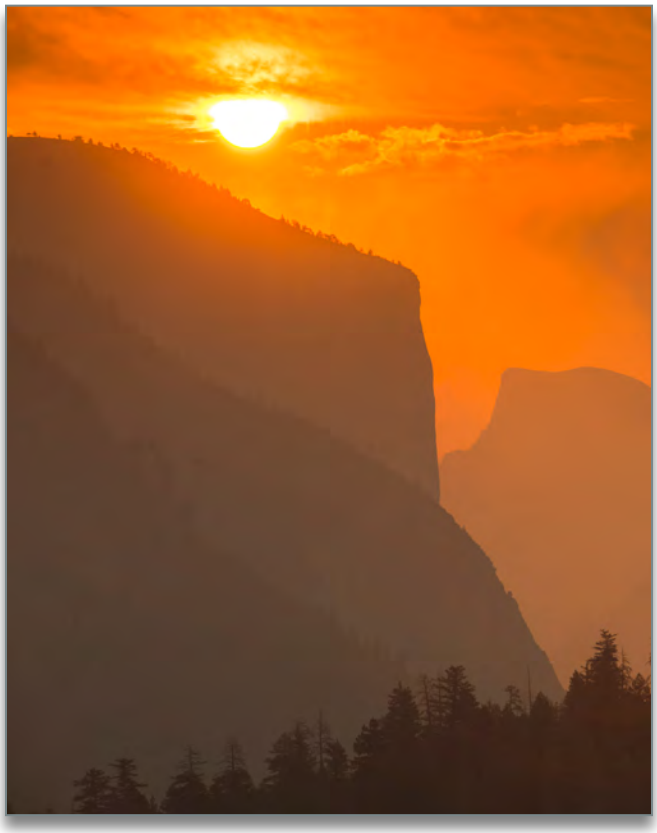
Traditional planning approaches of many conservation agencies, including the National Park Service, look to historical environmental conditions as a guide for the future and develop management strategies optimized to succeed under assumed "most likely" future conditions [15]. However, given the observed climate record over the past century and considering modeled ***climate projections***, scientists caution that historical environments (or "reference conditions") are not a reliable guide to the future [6, 16, 17].

In an era of rapid climate change, parks therefore need to plan for potential future conditions that may be quite different from the past (Figure 1). This entails adopting forward-looking goals and implementing strategies that specifically anticipate a range of possible ways in which the environment—and attendant effects on resources, infrastructure, and people—may change as the climate warms. Under such conditions of ***continuous change,*** managers will also need to examine the validity of underlying ***management goals*** against projected future conditions (see Step 3, page 34).

Figure 1. Forecast planning (depicted on the left) entails planning for one predicted future (typically within an acceptable margin of error). Such planning is most appropriate when there are aspects of the future that are controllable and considered likely. Scenario planning (depicted on the right) considers multiple potential futures as plausible. Scenarios build on what is known but also consider inherent unpredictability of complex systems.

Consider Future Climatic Conditions

Given uncertainties in the scope, magnitude, and effects of climate change, park planners are wise to consider multiple ***scenarios*** of the future for all but the shortest-term plans [18, 19, 20, 21] (see Box 1). Rather than try to determine and plan for a single expected future, as is done with ***forecasts*** or ***predictions***, parks can use scenarios to (1) explore a variety of plausible future conditions; (2) evaluate the implications of those conditions for their resources, infrastructure, and goals; and (3) identify a portfolio of possible management strategies.



BOX 1

USE OF THE TERM "SCENARIO" IN THIS GUIDE

Broadly speaking, scenarios are descriptions of plausible, alternative future conditions; they are not predictions or forecasts. The term "scenario" can apply at multiple stages in the adaptation planning process [58, 119, 125]. In much of the climate change literature, "climate scenarios" refer to plausible representations of future climate; their construction may use one of several different methods, including climate projections. Climate projections derive from models and identify potential future climatic conditions (e.g., changes in temperatures and precipitation) at global and/or regional scales under different "emission scenarios." Emission scenarios describe how greenhouse gas emissions could evolve in the future based on hypotheses about changes in human populations, demographics, economic growth, land use, technological development, etc.

There are numerous (>30) climate models that produce climate projections based on the emission scenarios; most planning processes apply the results from across several or all of these models. This guide refers to projections identified for use in the planning process as potential "climate futures" (i.e., climate projections from an ensemble of models), the underlying emission trajectories as "emission pathways," and the term "scenarios" to characterize climate futures plus their effects on park resources, assets, and values (i.e., the relevant climate change impacts, vulnerabilities, and risks, as described in Step 2 of the NPS adaptation planning process on page 26).

Dealing with uncertainty is not new to the National Park Service. Park planners and managers frequently face consequential decisions that cannot await more precise information regarding issues such as land use changes, socioeconomic activities, political realities, or changing climatic conditions.

Thinking through multiple scenarios is a useful approach to support planning and decisions despite imperfect information about future conditions [22, 23]. In fact, we routinely use scenarios to support decisions in everyday life.

IT MIGHT RAIN...DOES IT MATTER?

In walking to a restaurant under threatening skies, you decide to tolerate the risk of a storm. It's not worth the hassle of carrying an umbrella. If it rains, the consequences are minor and you can adjust, so you'll take your chances.

You're getting married in a year. In addition to plans for an outdoor wedding and reception by the lavender gardens, you rent the adjacent pavilion as a contingency against bad weather. If the weather is sunny, the pavilion will provide shaded space for guests to relax. If the day is rainy, the ceremony can proceed under cover. In either circumstance, renting the pavilion is a good investment.

These are examples of scenario planning. In both cases, you:

- consider plausible future conditions that could matter to the object(s) or purpose of your plan,
- assess the potential impact of those conditions on your plan and goals, and
- either consciously decide to accept the risks and consequences or develop strategies to enable your plan to succeed under a variety of conditions.

In planning for resource management, visitor use, or facilities in a park, what if your assumptions about how the future may develop are wrong? What is your level of risk tolerance? Does climate change matter for your decision? If your answer is "yes," it is wise to evaluate climate-informed scenarios in your planning process. Considering climate projections and potential effects through scenarios is beneficial for many types of plans in the National Park Service.

For climate adaptation, it is especially useful to consider multiple scenarios in the following situations:

- when the context is dynamic and uncertain,
- when developing a mid- to long-term (5+ to 7+ years) strategy or plan,
- when considering a large capital investment,
- when making a decision with potentially long-term or irreversible consequences, and/or
- when the goal is for long-term sustainability of the outcome of the decision.

Scenario planning can inform a range of possible management options. In some cases, it may be constructive to identify ***robust strategies*** that would be effective no matter which conditions unfold in the future [18]. For instance, a coastal park might install portable infrastructure so that it can continue to support visitor services under a range of future sea levels [24]. Considering multiple scenarios can also help parks proactively develop strategies to respond quickly when surprises occur. This might include putting contingencies in place to prepare for a potentially catastrophic event. For example, a park might plan for multiple escape options and routes for the evacuation of staff and visitors in the event of a quick-moving, unpredictable wildland fire. Indeed, dealing with the aftermath of Hurricane Sandy in 2012 underscored that climate-related events previously considered too extreme for inclusion in planning efforts are becoming increasingly likely, thus warranting consideration [25].

! **Numerous approaches for scenario planning exist,**

including a workshop-based methodology applied by the National Park Service at a number of parks across the country [19, 21]. A comprehensive workshop approach may not be feasible or necessary for all levels of park planning, thus, this guide offers an alternative, basic, "table top" methodology to help park planners and managers employ scenario-based thinking.

Act with Intentionality: Link Actions to Climate Impacts

Climate change adaptation is not a "new label" put on traditional actions. Rather, it intentionally and explicitly considers the influences of climate change on park resources, assets, and values when determining how to respond. Management responses that specifically consider climate impacts thus distinguish well-conceived and thoughtful adaptation from "business as usual," which may or may not continue to be appropriate under changing climatic conditions. Adapting to climate change may alter the location, timing, or way in which traditional management tools are applied and in some cases may require novel approaches and innovation as the National Park Service faces unique and unprecedented management and conservation challenges [26].

Because climate change is ongoing and dynamic, decisions made now will require reassessment over time. Accordingly, it is beneficial to structure adaptation strategies as hypotheses to be monitored, evaluated, and refined as needed—an approach supported by U.S. Department of the Interior (DOI) policy [27] and NPS commitment to ***adaptive management*** [28]. Providing transparency and documenting the rationale and science that connect management responses to climate impacts will greatly facilitate this process. Step 6 of the NPS adaptation planning process (page 48) further addresses monitoring to accompany implementation of adaptation actions.

Manage for Change, Not Just Persistence

Over the past century, resource management in national parks emphasized preserving existing fundamental processes and components, or where appropriate, restoration to a historical state [4, 29]. Efforts often focused on managing for ***natural conditions*** (for natural resources) and ***historic integrity*** (for cultural resources), with a desire to sustain these conditions in perpetuity [8].[4] In many parks, managing for the ***persistence*** of existing or historical conditions will continue to be a priority. For example, persistence will continue to be a fundamental goal of managing historic buildings, sites, or features. Over time, however, conditions across the National Park Service will diverge from those experienced in the past. Some areas, for example, may undergo ecological transformation, characterized by a high degree of turnover in species composition and not just loss or decline of a single species. Adaptation includes anticipating and planning for changing conditions that are "unlikely to stabilize" [30]. When focusing on the persistence of cultural or historic assets, for instance, managers will need to understand how the site and environmental context of these features may change, and whether and how such changes will affect their durability and significance [31].

In some cases, preparing for and accepting substantial change, ***transformation***, or even loss of certain resources, assets, and values may be warranted [32, 33, 34]. For example, at Bandelier National Park, drought associated with global climate change in 2002–2003 led to the death of most pinyon pine in the park's extensive pinyon-juniper woodlands [35]. Fires further transformed vast areas of Bandelier's landscapes, resulting in widespread conversion of pinyon-juniper and ponderosa forest to oak-locust shrublands [36]. At Cape Hatteras National Seashore, relocation of the lighthouse in 1999 required establishing a new National Historic Landmark Boundary and evaluating the integrity of the landscape while considering the location from the shore, and restored orientation and spatial arrangements among the station's four structures [37].

In practice, actions to respond to the effects of climate change encompass a range from resisting to directing change [38, 39]. NPS managers may focus on maintaining the persistence of resources and facilities by implementing strategies that resist change (***resistance strategies***).

4 Although NPS policy regarding natural resources revolves around the concept of "natural condition," managers seeking to reverse heavy and pervasive human impacts, in practice, frequently seek to manage toward historical conditions as the guide for closest approximation to the natural condition of the area.

When resisting change is not viable (e.g., the cost of resistance is exorbitant or the magnitude of potential change overwhelms the technical ability to preserve resources in their current state), managers will face the decision to accept changes (***acceptance strategies***).

For living resources, with multiple potential trajectories of change, managers may also actively direct the trajectory of change to a new desired condition (***directed change strategies***). For example, a boreal forest in Alaska may transition to a temperate forest or a grassland as a result of persistent directional climate change and how fire is managed.

These distinct but complementary categories of management strategies—resist, accept, or direct the trajectory of change (RAD framework, Table 1)—are useful for developing a broad suite of climate change adaptation options for natural resources having multiple, plausible trajectories of potential change [38, 39]. The structure of the framework promotes broad thinking by encouraging (1) development (brainstorming) of a wide range of potential adaptation responses that include actions in each category and (2) transparency in identifying what each potential action seeks to accomplish. The framework is particularly helpful in developing adaptation options for living resources (e.g., natural resources, cultural landscapes, some ethnographic resources), but may also prompt broader thinking for cultural resources, facilities, and visitor experience. Considering a broad range of adaptation responses and identifying the goal of adaptation actions applies to all aspects of NPS management (natural and cultural resources, facilities, visitor experience).

Table 1. RAD adaptation framework

RESIST the Trajectory of Change	ACCEPT the Trajectory of Change	DIRECT the Trajectory of Change
Managers may RESIST some changes because it is feasible to maintain resources/assets/values within desired conditions	Managers may ACCEPT changes because: ▫ altering the trajectory is infeasible ▫ effects are small and tolerable ▫ changes are acceptable to (or even desired by) stakeholders	Managers may DIRECT change toward a specific new state because it is feasible to steward change toward a more desirable outcome than what would be achieved with acceptance

The RAD adaptation framework offers a suite of management responses to climate change that ranges from resistance to directed transformation. It is most useful for living resources but may also inform options for cultural resources, facilities, and visitor experience. Originally described as Resist-Accommodate-Direct [38, 39], the RAD framework expands on earlier work (e.g., [40, 41]) as a foundation for NPS planning under conditions imposed by climate change. NPS collaboration with partners, particularly the Federal Navigating Ecological Transformation working group, produced the current Resist-Accept-Direct formulation with definitions of the three terms further clarified in Thompson et al. 2020 [42].

Adaptation can involve a variety of approaches, and the appropriate response strategy will vary across resources, space, and time. Strategies suggested here can work in complementary ways. For example, a manager might seek to buy time for a particular resource or asset for as long as possible by resisting change and managing for persistence. At a certain point, this may no longer be tenable, and management strategies might shift to either accepting or actively directing change to preferred new conditions [7, 40], after which the focus might again shift to resisting change in managing for persistence of the new conditions.

Efforts to enhance resilience are often cited as a viable adaptation strategy, although the concept requires careful thought and definition to be meaningful in practice (see Box 2). Increasingly, parks will need to determine when managing for persistence is warranted and possible, when accepting or managing for change is more appropriate, and when it may be necessary to cycle between these.

This type of flexible management is not new for park managers who routinely make pragmatic choices about protection priorities and resource investments. What may be different is being explicit about these choices and acknowledging departure from "natural" conditions given the continuing nature of changes driven by a rapidly changing climate.

Reconsider Existing Management Goals, Not Just Strategies and Actions

As climate change continues, some existing long-term management goals may no longer be feasible. Consequently, successful climate adaptation requires considering the influence of climate change on our continued ability to meet current goals [30]. This may either validate the continued relevance of existing goals or indicate the need for updates [43]. An analysis of existing goals offers an important opportunity to establish or adjust ***desired conditions*** for the future based on sound science regarding climate projections and impacts. Parks in these situations are encouraged to formulate ***climate-informed goals***, which seek to strike a balance between traditional aspirations and emerging realities.

BOX 2

WHAT'S "RESILIENCE" GOT TO DO WITH IT?

The concept of resilience features prominently in the NPS *Climate Change Response Strategy* and many other adaptation-related policies and programs across the country. However, what the term represents is often ambiguous and applied in a variety of ways across disciplines [29, 123, 117, 119, 127]. Current definitions of "resilience" encompass the full range of adaptation responses, from persistence (seeking to maintain current conditions or return to a particular functional state) to realignment (having the capacity to change, adapt, and reorganize to be better prepared for climate impacts) [114].

Thus, if used without definition, the term "resilience" will lead to confusion. Park plans and management decisions that elect to use this term should be careful to define its use in terms of intent and desired outcomes for the resources or assets of interest [29].

National Park Service Adaptation Planning Process

The NPS adaptation planning process (Figure 2) is an adaptive management framework that reflects familiar stages of planning and specifically addresses the implications of climate change. As reflected in the planning cycle, adaptation is a continuing process, rather than an endpoint.

Adaptation is fundamentally about risk management; thus it is essential to identify and mitigate vulnerabilities and risks (Step 2) under multiple plausible scenarios of future conditions (represented below by circles outlined in thick blue). Whether creating a new plan or updating an existing one, the fundamental components and sequencing are an effective way to address climate change in most NPS planning processes. Note that it is common to revisit some steps based on information developed in subsequent steps. For example, based on monitoring the effectiveness of adaptation actions (Step 6), a park may elect to modify the strategies selected in Step 5.

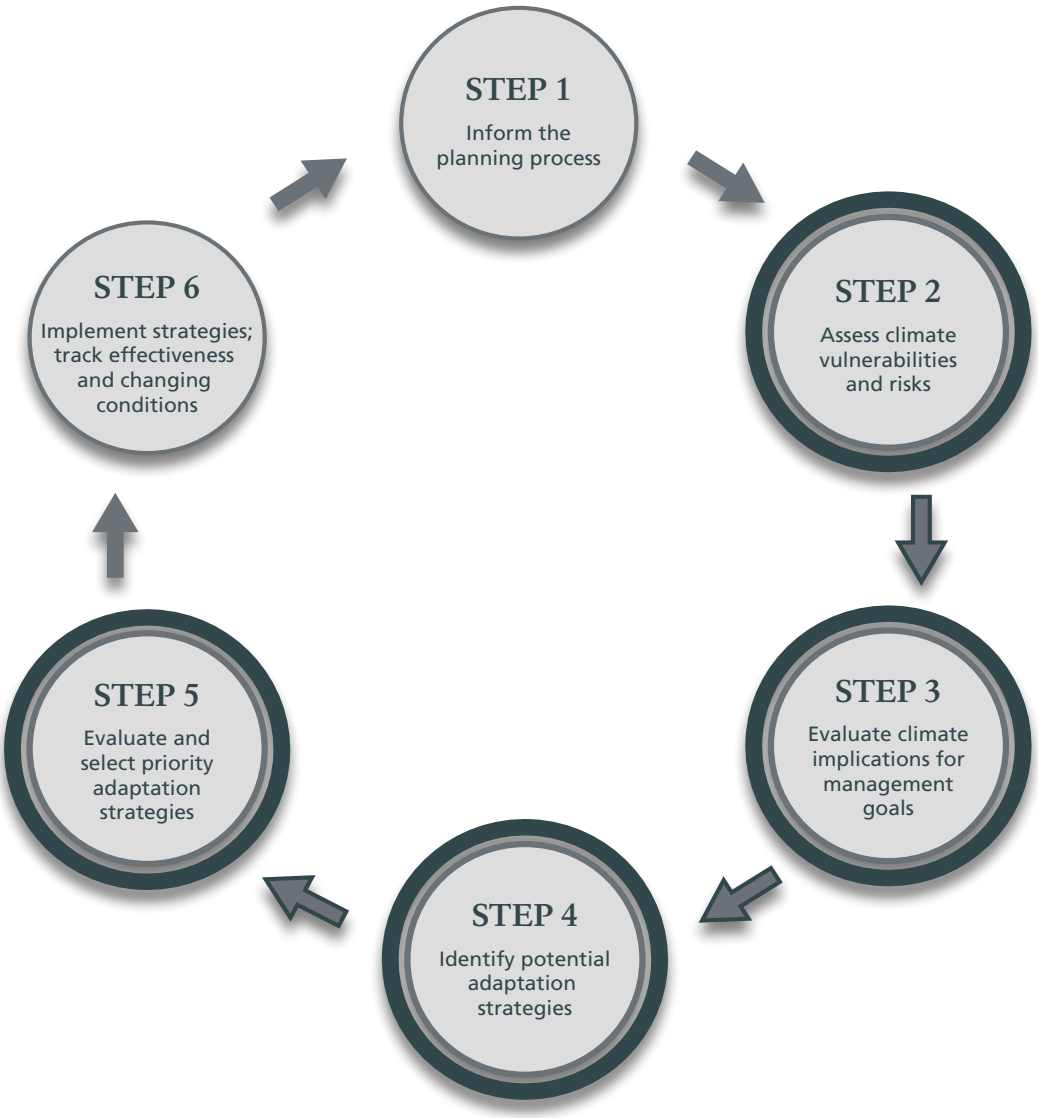


Figure 2. Generalized NPS adaptation planning process. The concentric circles of Steps 2 through 5 represent multiple scenarios for consideration.

Overview of the National Park Service Adaptation Planning Process

Much of NPS adaptation planning aligns with the preliminary project planning process and (for NEPA analyses, strategic or implementation plans) informs alternatives development. This is a structured approach for planners and managers to assess how current and future climate change may affect park units and to develop strategies that reduce climate-related vulnerabilities and risks to meet goals of the planning purpose (Box 3).

The essence of the process is simple. Regardless of the type of plan, planners and managers should ask the following:

- What is the range of climate projections for my area?
- If the climate changes according to the climate projections, what are the likely effects on and risks to resources or assets that are the focus of this planning effort?
- Are these risks consequential; do they matter to the purpose of this plan?
- If so, what strategies and actions could mitigate these risks?
- Do I need to modify my goals and are they attainable?

BOX 3

SUMMARY OF THE NPS ADAPTATION PLANNING PROCESS

Step 1. Inform the planning process

- Define scope and current management goals
- Engage participants and partners
- Compile relevant background and context information

Step 2. Assess climate vulnerabilities and risks

- Identify projected climate futures
- Assess climate vulnerabilities and risks

Step 3. Evaluate climate implications for management goals

- Assess continued feasibility of current goals
- Identify modifications or updates for climate-compromised goals

Step 4. Identify potential adaptation strategies

- Identify array of strategies to address important climate risks

Step 5. Evaluate and select priority adaptation strategies

- Evaluate and compare promising adaptation strategies
- Select priority adaptation strategies

Step 6. Implement strategies; track changing conditions and adaptation effectiveness

- Implement priority adaptation strategies
- Evaluate the implementation and effectiveness of adaptation strategies and actions
- Monitor conditions to assess how the future is emerging
- Document outcomes and adjust actions and plans as needed

These steps build on and draw from one another. It is an iterative process, thus documenting information, assumptions, and decisions in each step can support future refinements based on new information or changing conditions or assumptions.

Step 1. Inform the planning process. In Step 1, as part of preliminary project planning, planners and managers specify which park resources, assets, or values are the focus of the planning effort; clarify existing management goals related to those features; define the spatial and temporal scope of the planning; begin engaging with key internal and external participants; and compile relevant context and background information.

Step 2. Assess climate vulnerabilities and risks. Step 2 focuses on projecting future conditions and assessing how those changes may affect the park, specifically the focus of the plan defined in Step 1. Here, planners and managers identify projected future climatic and other conditions, and consider which resources and assets are most vulnerable to those changes and the reasons for those vulnerabilities. This is the basis for identifying which impacts and vulnerabilities pose the greatest risks to sustaining the park's mission and achieving its management goals.

Step 3. Evaluate climate implications for management goals. Step 3 focuses on evaluating whether current management goals will continue to be feasible and relevant in light of expected changes. Planners then consider if and how goals may need to be refined, updated, or perhaps replaced to provide climate-informed goals.

Step 4. Identify potential adaptation strategies. In Step 4, planners and managers focus on identifying the broadest array of possible strategies to address climate vulnerabilities and risks. This is the stage in the planning process for creativity and innovation, including consideration of approaches that may not be immediately actionable, but could become more viable as the impacts of climate change accelerate.

Step 5. Evaluate and select priority adaptation strategies. Step 5 focuses on distilling the full array of possible adaptation responses (from Step 4) into strategies that best achieve the park's climate-informed goals. To do so, planners and managers evaluate and select strategies based on longer-term adaptation needs and near-term implementation considerations, including technical feasibility as well as legal, financial, or social constraints and opportunities. Commensurate with park goals, selected strategies will reflect a decision to either resist, accept, or work to direct the trajectory of climate change effects toward more desirable conditions.

Step 6. Implement strategies; track effectiveness and changing conditions. Step 6 entails implementing the plan and monitoring the results of adaptation efforts to ensure that strategies and actions provide the desired effect. Monitoring results can help park managers identify any necessary changes in tactics. The design of monitoring and evaluation must accommodate immediate needs of the park while also considering changing environmental conditions, future projections, and novel and unexpected circumstances that may arise from climate change.

Adaptation Planning in Action

A growing number of climate adaptation efforts are either underway or completed at national parks across the country. The following case studies reflect a diversity of climate concerns, planning approaches, and adaptation strategies.[5]

Acadia National Park (Maine):

Over the past decade, Acadia National Park experienced extreme flooding and erosion events that damaged historic roads and trails and redeposited gravel into adjacent wetlands [44]. Aging and undersized culverts have been inadequate to effectively and safely transmit streamflow, a challenge that is projected to become more significant under future climatic conditions [45]. To address this risk, the park incorporated climate change scenarios and hydrological modeling data into its transportation infrastructure rehabilitation efforts. Increasing culvert sizes to accommodate changing flood conditions may enhance connectivity for aquatic organisms, such as fish that may need to move in response to climate-induced changes in suitable habitat, as long as those culverts are intentionally designed with aquatic organism passage considerations in mind (Figure 3).

Figure 3. In 2010, Acadia National Park replaced old corrugated metal culverts with larger concrete open box culverts—like this one on Wildwood Stables Road—to move greater volumes of water and allow the unimpeded movement of fish. NPS Photo.

5 Select examples available as of 2021

Assateague Island National Seashore (Maryland, Virginia):

Under most climate projections, Assateague Island National Seashore is expected to experience increasing erosion, overwash, inlet breaching, and shoreline retreat [46, 47]. The park practices climate change adaptation on an ongoing basis and through forward-thinking adaptation measures in the park's general management plan [48], which plans for a long-term shifting of seashore facilities and assets to more stable locations both on and off the island. Based on shoreline monitoring data and projections for sea-level rise and storm surge, the park determined suitable locations and configurations for new parking lots and uses native materials for paving (crushed oyster shells over a clay base) that are more cost effective and easily removed and re-applied if the lots must be relocated [49]. In addition, park managers invested in portable infrastructure, such as readily removable bathhouses, to ensure that increasingly severe storms do not destroy facilities (Figure 4).

Figure 4. Rather than make big investments in traditional brick-and-mortar structures that sustain damage with the frequent passage of storms, Assateague Island National Seashore purchased over a dozen moveable restroom facilities. The structures can be moved to a less vulnerable location with enough notice and then restored to their original locations when conditions are safe. NPS Photo.

Denali National Park and Preserve (Alaska):

Rapidly thawing permafrost due to higher temperatures is contributing to increased risks from landslides, which have the potential to significantly disrupt transportation and threaten public safety. Along the park's only road, the Pretty Rocks Landslide evolved from a minor maintenance concern two decades ago to what park managers view as an "existential threat" to park visitation [50]. The park is currently grappling with decisions about how long the current road alignments can or should be maintained and what reconstruction or rerouting options are feasible (Figure 5). These challenges will continue to grow, as research suggests that the total area of "stable," near-surface permafrost could decline from approximately 49% of total area in Denali during the decade 2000s to 6% by the 2050s and 1% by the 2090s [51]. This thaw will likely increase the number and severity of future landslides.

Figure 5. Core samples taken at Pretty Rocks in 2018 indicate how much ice underlies this part of the road through Denali National Park and Preserve. Loss of permafrost contributes to increased risk of landslides along the park road. NPS Photo.

Fort Pulaski National Monument (Georgia):

The National Park Service, working with the US Army Corps of Engineers, constructed a revetment and living shoreline in 2013 to protect the historic Cockspur Island Lighthouse in Georgia's Fort Pulaski National Monument against erosion and accelerated sea-level rise (Figure 6). The new revetment incorporates a wider base than currently required, enabling the addition of rock to extend its height as sea levels rise in the future. Ongoing oyster bed restoration and marsh recruitment on the island's west side provide additional island stabilization.

Figure 6. Situated on an islet off the southeastern tip of Cockspur Island, the Cockspur Lighthouse at Fort Pulaski National Monument stands 12 miles east of the port of Savannah. The islet—comprised of oyster shells and marsh grass—is now regularly covered by high tide. NPS Photo.

Gateway National Recreation Area (New York, New Jersey):

In developing the general management plan for Gateway National Recreation Area, the planning and management team identified climate change and related projections of sea-level rise as "(describing) a new reality and urgency to find ways to protect, improve, and sustain the park's natural and cultural resources. . .." In addition to incorporating vulnerability assessments, sustainable designs, and adaptive management procedures into long-term planning and operations, the park also developed a prioritized list of historic resources to inform future preservation efforts, funding, and maintenance. The park encompasses nine National Register Districts and over 330 historic structures and associated landscapes. An interdisciplinary team with expertise in history, architecture, cultural landscapes, and business services developed a process to evaluate each site and structure against nine criteria, including climate change vulnerability (vulnerability to future storm events) [52] (Figure 7).

	Band	Fundamental Resource	National Register Status	Level of Significance	Potential Use	Uniqueness	Visibility	Climate Change Vulnerability
Playing Courts	Ruin	No	NR-District	State/Local/ Contributing	Vacant - High Potential for Reuse	Common	Accessible	Moderate
Boardwalk/ Promenade	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Uncommon	Prominent	Significant
Mall	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Prominent	Minimal
Lighting -Type A, B and 1931	Preserve	No	NR-District	State/Local/ Contributing	Occupied	Uncommon	Prominent	Minimal
Wise Clock	Preserve	No	NR-District	State/Local/ Contributing	Occupied	Uncommon	Prominent	Minimal
Silver Gull Beach Club Historic District								
Clubhouse	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate
Cabanas [A,B,C & D]	Ruin	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Significant
Gatehouses - East and West	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate
Breezy Point Surf Club Historic District								
Barracks	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate
Bayberry Room	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate
Birdhouse	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate
Gatehouse	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate
Cabanas A,B,C,D,W	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate
Bath Cabins E,F	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate
Original Court Restrooms/ Showers	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate
Administration Building	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate
Cafeteria/Ballroom	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate
Ocean Court Cabins [008-212]	Stabilize	No	NR-District	State/Local/ Contributing	Occupied	Common	Remote	Moderate

Figure 7. Among other variables, the general management plan for Gateway National Recreation area assesses the climate change vulnerability of historic resources in the park. The far-right column references site condition prior to the passage of Hurricane Sandy in 2012. NPS Graphic.

Glacier National Park (Montana):

Confronted with invasive lake trout, increasing stream temperatures, and a reduction in late-season sources of cold water from glaciers, managers at Glacier National Park translocated bull trout stocks above an impassable waterfall to upstream areas that are projected to remain as cooler water refugia amid changing climatic conditions and offer safe havens from nonnative trout [53] (Figure 8).

Figure 8. Juvenile bull trout swims through the water above a juvenile westslope cutthroat trout in Glacier National Park. NPS Photo.

Gulf Islands National Seashore (Florida, Mississippi):

Sea-level rise and more-intense coastal storms frequently damage roads at Gulf Islands National Seashore and the surrounding community, at times rendering the Fort Pickens Historic District inaccessible [54]. In the face of growing risks due to sea-level rise driven by climate change, the park is working with the City of Pensacola and Escambia County to establish an alternative transportation system to reduce road maintenance costs and ensure access to Fort Pickens and beaches (Figure 9). The park is also engaged in a large-scale project called the Mississippi Coastal Improvements Program, which involves restoration of multiple barrier islands by recreating sediment transport processes and replacing sediment lost to dredging and storms [55]. Goals of the project include maintenance of the estuarine ecosystem of the Mississippi Sound and reduction of storm damage along the mainland coast.

Figure 9. The Turtle Runner ferry boat approaches Fort Pickens at Gulf Islands National Park. NPS Photo.

Hawai'i Volcanoes National Park (Hawai'i):

A combination of El Niño-Southern Oscillation events and climate change exacerbate warming and drying conditions in Hawai'i, particularly at higher elevations. These changes have significantly impacted rare plant populations, and climate models project a dramatic shift and/or reduction in climatically suitable areas for many native plant species in coming decades. To address these risks, the park is establishing satellite populations of numerous rare and endangered species within their modeled ecological range to help build their capacity to persist as climatic conditions change [56] (Figure 10).

Figure 10. Owing to both its cultural and ecological importance, the 'Ohi'a lehua (*Metrosideros polymorpha*) is one of many plant species of management concern at Hawai'i Volcanoes National Park. NPS Photo.

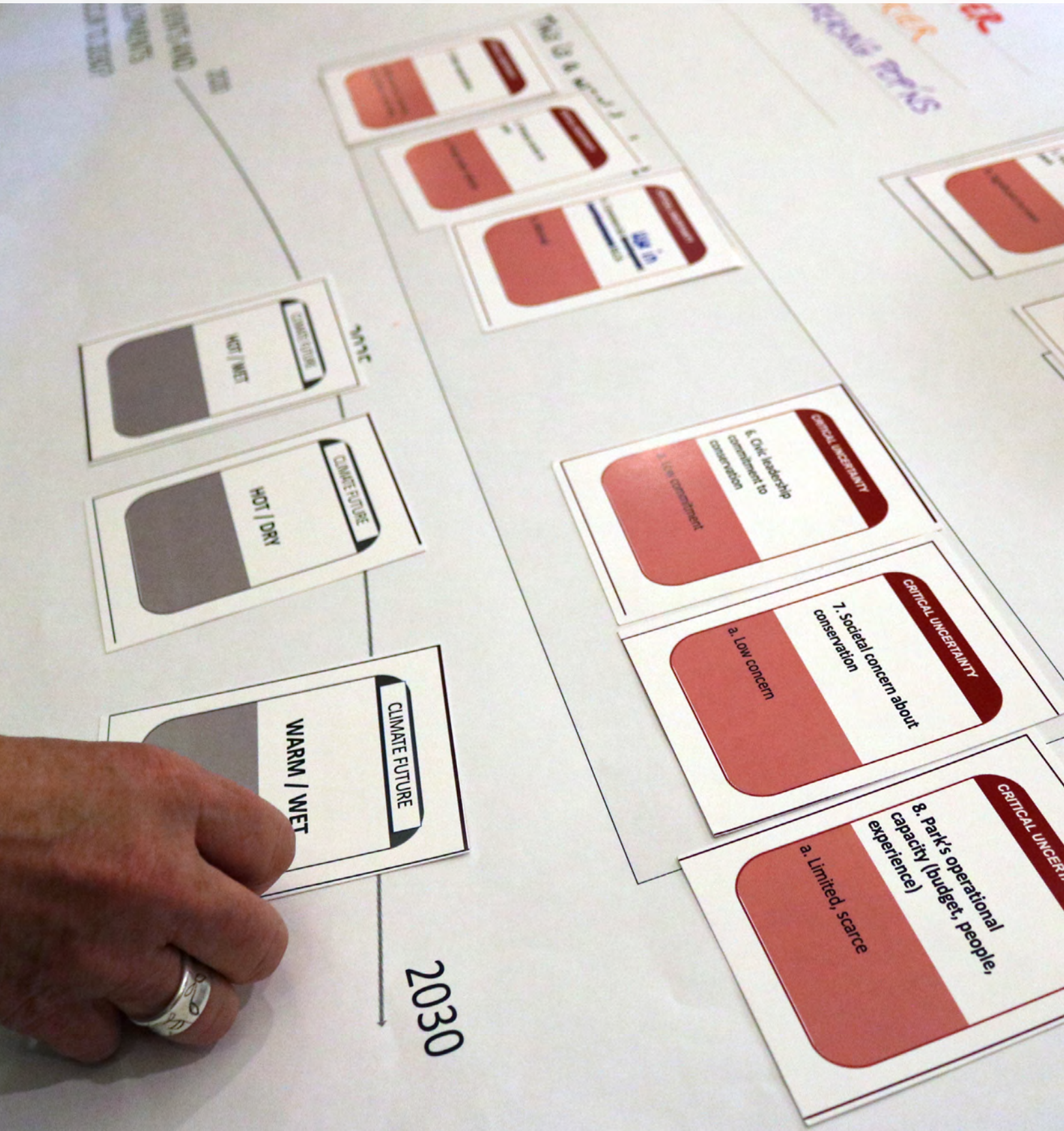
North Cascades National Park (Washington):

Hydrology of the Stehekin River in the North Cascades National Park Complex is shifting from a system dominated by spring floods during snowmelt to one dominated by winter floods resulting from rain-on-snow events [57]. This change has led to larger, more-frequent flooding events, with substantial impacts on park resources and infrastructure (Figure 11). In response, and consistent with its Foundation Document (2012) that identifies climate change as a key issue and the Stehekin River as a fundamental resource, the park developed an adaptation plan that includes relocating sections of road, moving administrative facilities and staff housing out of the floodplain, relocating vulnerable campgrounds, and restoring riparian habitat. These actions will reduce the risk of future flood damage by enabling the Stehekin River to fully occupy its floodplain, moving within its channel migration zone over time. They will also reduce NPS administrative costs, protect the Stehekin Community, sustain opportunities for public enjoyment of Lake Chelan National Recreation Area, and maintain access to North Cascades National Park [58].

Figure 11. In 2013 a powerful storm cell triggered a massive mud and rockslide down the Imus Creek drainage in the community of Stehekin, Washington in the North Cascades National Park Complex. NPS Photo.

SECTION TWO

NPS ADAPTATION PLANNING PROCESS



Step 1: Inform the Planning Process

Establishing a solid foundation for any planning effort is essential to produce meaningful results. Step 1 sets the context for the adaptation planning process

Step 1 Key Concepts

- Clearly articulate *current* management goals. This is essential for effective adaptation planning because climate change may undermine the feasibility of achieving some goals.
- Wide-ranging impacts of climate change will often require consideration of a broader geography and longer time frame.
- Addressing climate concerns may require engagement with new or additional participants and partners (e.g., climate scientists).

The general process for Step 1 includes the following activities:

- Define scope and current management goals
  - Consult the park's foundation document
  - Identify focus of the planning effort (e.g., resources, infrastructure, visitor experience)
  - Clarify current management goals
  - Define geographic scope and time frame
- Engage key participants and partners
- Compile relevant background and context information

Define Scope and Current Management Goals

Consult the Park's Foundation Document

Park foundation documents establish the context and underlying guidance for park planning. Foundation documents identify key issues, describe the significance and purpose of the park, legal and policy requirements, interpretive themes, and fundamental resources and values. This information is a starting point for all park plans, and frames fundamental values to be protected.

Identify Focus of the Planning Effort

Specifying the intended focus of the adaptation planning effort—referenced in this guide as ***resources, assets, and values***—is key to shaping the overall adaptation planning process and serves as the basis for identifying significant climate concerns. Note that "resources, assets, and values" (sometimes referenced simply as "resources and assets") are generic terms to encompass Fundamental Resources and Values (FRVs) and Other Important Resources and Values (OIRVs) as identified in a park foundation document, in addition to any other resources and/or facilities, infrastructure, and visitor experience.

Given the breadth of NPS planning processes, the focus of a planning process may vary widely, including, but not limited to, park infrastructure and facilities; particular species, habitats, iconic natural features, or ***wilderness character***; visitor use and experience; and historic structures, archaeological features, museum collections, ethnographic resources, or cultural landscapes, as identified in park foundation documents and other sources. It is also important to note that evaluating climate risks during the adaptation process may reveal new or different assets or features requiring attention.

Clarify Current Management Goals

Clear articulation of current management goals is an important starting point for any planning process and is central to developing adaptation strategies. Climate change may affect the feasibility of achieving existing goals regardless of their basis in law or policy; thus, it is essential to document any existing goals in order to consider their viability under climate change.

Existing management goals typically derive from policies and legal mandates, enabling legislation, foundation documents, and park planning portfolios. Sometimes current management goals are not recorded anywhere and exist only as ongoing practice. In such cases, this step may entail simply writing a description of existing management practices, what they intend to achieve, and why. If the planning effort addresses a completely new situation, new goals are developed as part of Step 3.

Define Geographic Scope and Time Frame

Because climate change has wide-ranging effects across regional landscapes, adaptation planning typically requires a broadening of spatial and temporal scope, resulting in consideration of larger geographies and longer planning horizons. Considering park planning in a broader spatial context is particularly important to address challenges such as shifts in habitats and species ranges, regional-scale disturbances (e.g., wildland fires or flooding), and competing demands for increasingly scarce land and water resources.

The continuous and accelerating nature of climate change also means that considering longer time frames will be important for adaptation planning. Effectively stewarding NPS resources for future generations requires that planning horizons extend well into the future. A core challenge is to address short-term planning needs without losing sight of potentially serious impacts that may occur over a longer term, or those that could occur suddenly (e.g., major disturbances such as wildland fires or hurricanes). Determining the appropriate time frames depends on multiple factors, including availability of climate projections, the time period for a plan or decision, or life span of an investment or asset [59]. Indeed, considering climatic conditions over a 25-, 50-, or even 100-year time horizon can provide important strategic context even for near-term decisions, such as:

- Siting and designing new facilities that have a long life span and high cost;
- Acquiring or working with partners to acquire new conservation areas to facilitate shifts in habitat or species ranges;
- Determining the capacity and location of infrastructure investments—such as stormwater drainage systems and heating, ventilation, and air conditioning (HVAC)—to accommodate increasing or new demands;
- Choosing which tree species or genotypes to use in forest restoration efforts; or
- Prioritizing inventories and documentation of cultural resources.

Engage Key Participants and Partners

In addition to participants and partners that typically would engage in a particular NPS planning process, incorporating climate considerations may require additional collaborations and expertise, including climate scientists and adaptation specialists, both internal and external to the National Park Service. Appendix A summarizes useful resources for accessing climate-related information and expertise. Additionally, planning across a larger geographic area may require engagement with stakeholders and partners beyond those in the immediate vicinity and may include landowners; tribes; and other federal, state, local, or municipal jurisdictions.

Compile Relevant Background and Context Information

NPS planners and managers are accustomed to compiling a wide array of information on background and context to support planning efforts. This includes data (e.g., natural and cultural resource inventories and condition assessments, threatened or endangered species data, visitor use data) and context information (e.g., enabling legislation, park zoning, wilderness status, special use permits, rights-of-way). Sources for this information include park planners and staff and Regional Planning Portfolio Managers. In addition to traditional sources, incorporating climate concerns into NPS plans requires additional information, including projections of future climatic conditions and potential resource responses. Compiling available climate information early in the planning process—whether from regional or more park-specific sources—can help planners identify potential climate concerns and data gaps.

! The NPS Climate Change Response Program (CCRP) and other providers of climate science can help compile and access relevant climate information and provide technical assistance to use these data in planning and decisions. Numerous sources of information and resources for generating needed climate information are available (see Appendix A). Planners may contact any CCRP staff to discuss information needs, or submit a request for CCRP assistance through the NPS Solutions through Technical Assistance Requests (STAR program).

Step 2: Assess Climate Vulnerabilities and Risks

At its core, climate adaptation is about risk management. Accordingly, most adaptation strategies seek to reduce climate-related vulnerabilities and risks to valued resources and assets. Thus, understanding how, where, and when climatic changes may affect a park is fundamental to adaptation planning. This phase of the adaptation cycle focuses on two major activities: (1) understanding climate projections of future climatic conditions; and (2) assessing their potential effects on the resources, assets, or values of interest.

A fundamental approach for adaptation planning is consideration of more than one scenario of plausible future conditions.

Numerous methods exist for developing and applying scenarios, some of which are complex and time consuming, while others are fairly basic and rapid. Similarly, multiple approaches to assess climate vulnerability and risk exist, ranging from rapid estimates based on expert opinion to more analytical and computationally intensive techniques. In both instances, planners should evaluate the level of complexity and rigor needed to meet their specific needs. Such considerations may include: the intended application of the planning effort (e.g., decisions about large capital investments or irreversible effects on resources vs short term operational adjustments); the expertise and capacity of staff and partners; and available time and budget.

The process for Step 2 described below assumes a basic to moderate capacity, as well as access to expertise. A variety of guidance documents are available to assist in scenario development or vulnerability assessment techniques, including more-intensive or less-demanding approaches [19, 20, 21, 60, 61]. NPS CCRP staff are also available to advise or assist in identifying projected climate futures specific to a particular park and considering their implications for park resources and assets.

Step 2 Key Concepts

- Understanding climate-related vulnerabilities and risks is the foundation for crafting meaningful adaptation strategies.
- Projecting future climatic conditions is necessary to assess the exposure of park resources and assets to climate-related changes.
- Considering more than one climate future is an effective means to plan for dynamic and uncertain climatic conditions.

Distinguishing among Climate Drivers, Impacts, Vulnerabilities, and Risks

Related, but seemingly overlapping, concepts associated with climate change and its effects can be confusing. This guide distinguishes among the terms *climate drivers*, *impacts*, *vulnerability*, and *risk*, which describe information fundamental to adaptation planning.

Climate drivers. As used in this guide, ***climate drivers*** (sometimes referred to as climate metrics or variables) are any climate-related factors (e.g., temperature, precipitation, sea level) that directly or indirectly affect, or have the potential to affect, a park's resources and assets (see Box 4).

BOX 4

IDENTIFYING RELEVANT CLIMATE DRIVERS

The climate drivers most relevant for a given adaptation planning effort highly depends on the environment and the focus of the planning effort. In most cases, changes in temperature, precipitation, and locally relevant extreme climate events (drought, heavy rains, storm surge) will be important. The NPS CCRP staff or a consultant can summarize basic climate drivers in a relatively simple table, such as Table 2. Numerous other climate metrics/variables are available and can be derived in ways most relevant to the planning need (e.g., monthly, seasonally, daily, above/below thresholds). Appendix B includes a much longer list of climate drivers, which may help planners and park staff identify factors that are particularly important to park resources or infrastructure. Many NPS plans would benefit from near-term climate projections. Projections spanning the range of years from 2020 to 2050 are the most near-term figures that can credibly be produced. Long-range plans (e.g., major infrastructure construction, species relocations) may require projections to 2100 or beyond.

Table 2. Example table of climate drivers for three potential climate futures (named for ease in referencing), showing changes projected from the present to 2040.

Climate Driver (change from historical by 2040)	Getting Warmer	Hot and Smoky	Summer Tropics
Spring/fall temperatures	+2°F	+3°F	+5°F
Annual beetle-killing cold days	-7	-15	-7
Summer rainfall	0%	-20%	+20%
Summer base stream flow	-5%	-15%	+15%
Stream temperatures (+/- 0° F)	+2°F	+4°F	0°F
Annual fire season length (days)	+12	+30	-5
Seasonal snow cover	-10%	-30%	0%

Impacts. Climate change ***impacts*** are the specific observed or anticipated effects of climate drivers on natural and human systems. These include physical impacts (e.g., effects on geophysical systems, such as floods, droughts, and coastal erosion) as well as associated effects on infrastructure, species ranges, ecosystem function, or recreational opportunities. Although common usage of the term "impact" implies an adverse outcome, other usages adhere to the dictionary definition of "a marked effect or influence" [62]. In this context, the effect or "impact" could be detrimental, beneficial, or neutral.

"Climate change impacts" refers to direct and indirect effects of climate change on natural or human systems, as distinct from the term "impacts" in NEPA analyses, which are potential effects of a management action on aspects of the human environment (organized as "impact topics" in NPS NEPA documents) [11].

Vulnerability. Climate change ***vulnerability***, in contrast, *does* imply an adverse outcome and is characterized as the extent to which a species, habitat, ecosystem, cultural feature, park facility, or other relevant resource is susceptible to and unable to cope with direct and indirect impacts of climate change [60].

Risk. *Risk* is a related concept that in formal application refers to the likelihood that something will happen (i.e., the probability of an event occurring), combined with the consequences if it does occur (i.e., the magnitude of harm). For purposes of this guide, the concept of risk is used to highlight climate impacts and vulnerabilities that pose the greatest consequences for the park's mission or goals and therefore should be a focus of adaptation measures designed to reduce those risks.

Although these concepts are related, different sectors and disciplines may emphasize or use one over another. Regardless of whether you use the concept of impacts, vulnerability, or risk—or some combination of the three—Step 2 is about documenting how climate-related changes may affect the park's resources, assets, and values in order to inform later steps in the adaptation planning process.

Step 2 consists of the following activities:

- Identify projected climate futures
  - Identify key climate threats and drivers
  - Describe two or more climate futures
- Assess climate vulnerabilities and risks
  - Assess vulnerabilities under each climate future
  - Summarize impacts or vulnerabilities in scenarios of future conditions
  - Identify highest risks to achieving desired outcomes under each scenario

Identify Projected Climate Futures[6]

Identify Key Climate Threats and Drivers

Building on the preliminary climate information gathered in Step 1, consider which climate drivers would most affect the resources or assets that are the subject of the planning effort. In addition to direct effects from temperature or precipitation changes, it is important to consider indirect effects such as seasonal changes, extreme events, or changes in disturbance regimes.

Identifying current or anticipated effects that are of particular concern can illuminate which climate drivers are most important. Most park managers have sound judgment and common-sense knowledge of key climate-related issues that could affect park resources and assets (e.g., accelerated shoreline erosion near historic coastal structures or archeological resources, an increase in wildland fire frequency and severity for forests, or implications of potential shifts in visitor use for long-term infrastructure planning and staffing). Beginning with those initial concerns can expedite the process for identifying important climate drivers associated with those impacts.

Another way to identify relevant climate drivers is to consider the sensitivity of resources and assets to changing conditions and their potential for exposure to those changes (see also *Assess Vulnerabilities under Each Climate Future*). For example:

- Some visitor opportunities and experiences are sensitive to changes in seasonal climatic conditions, such as earlier spring warming or reduced winter snowpack, which may result in altered visitation trends (e.g., an increase in visitors during ***shoulder seasons*** or a decline in winter sport opportunities) [63]. In this case, relevant climate drivers might include shifts in seasonal temperatures and precipitation patterns.
- Potential exposure to an increase in the frequency or intensity of heat waves may be an important climate driver for roadway maintenance and construction decisions where pavement may be sensitive to high temperatures, which can contribute to pavement buckling [32, 64].

6 Staff of the NPS Climate Change Response Program are available to assist.

Climate change as a threat multiplier. Climate change does not happen in a vacuum and often serves as a ***threat multiplier*** by altering the timing, location, or magnitude of existing threats. Thus, it is beneficial to consider data regarding compounding effects of climate change that influence park resources and facilities. For example:

- Higher temperatures worsen nitrogen, sulfur, and ground-level ozone pollution in the Great Smoky Mountains National Park, contributing to acidification of streams and soils, reducing visibility, and placing visitor health at risk [65].
- Accelerated sea-level rise and more-intense storm surge events associated with climate change exacerbate existing shoreline erosion caused by hardened structures such as bulkheads, seawalls, and jetties on adjacent sites (e.g., at Assateague Island National Seashore), placing roads, visitor facilities, and recreational beaches at increased risk from storms and sea-level rise [24].
- Efforts to protect or relocate communities in response to rising sea levels may adversely affect archeological sites and other cultural resources across the southeastern Atlantic and Gulf coasts [66].
- In Haleakalā and Saguaro National Parks, climate change intensifies the existing threat from invasive flammable grasses. Under a warming climate, these invasive plants promote more intense and frequent fires, and increase the susceptibility of dryland forests, shrubland, and desert systems to wildland fire [67, 68].

Consideration of other factors. Economic, social, and political trends can be significant drivers of change, and parks may find it worthwhile to address some of these broader factors in developing scenarios. Incorporating socioeconomic factors adds complexity to the scenario-development process but can be a useful way to better understand various ***non-climate drivers*** and how they might shape future conditions affecting park management. For example:

- Increased development in areas neighboring parks can create a greater risk of invasive species due to the presence of disturbed areas and roads that facilitate their growth and transport [69].
- Economic recession can reduce park visitation numbers, which could mean reduced spending and associated revenues for a park and its surrounding communities [70].
- The potential for public opposition could limit the ability of parks to implement some climate adaptation strategies that might be considered contentious, such as translocation of species or abandonment of iconic cultural resources [71, 72, 73].

Describe Two or More Climate Futures

Using the drivers considered most important for the decision(s) at hand, the next step is to describe a range of possible future climatic conditions. Organizing climate drivers by their relative degrees of uncertainty will help illuminate those that are most useful for a scenario planning exercise. In particular, factors that represent "critical uncertainties" (i.e., they are both important and are characterized by many unknowns) will be especially useful for stimulating creative "what if" thinking [19].

Scientists describe uncertainty in climate drivers as related to the direction, amount, and/or rate of projected change. For instance, the US National Climate Assessment [74] and the Intergovernmental Panel on Climate Change (IPCC) [6, 75] reports articulate sources and degrees of uncertainty for the range of climate variables and associated impacts reported. For some climate drivers, the directional trend may be clear (e.g., higher temperatures, higher global sea levels), but uncertainty exists about the rate and magnitude of such changes. Other projections may be characterized by uncertainty in both the direction and pace of change. For instance, climate scientists generally have greater confidence in modeled projections for changes in average temperatures than those for average precipitation [74].

Typically, global and regional climate projections are presented as ranges (e.g., a 2^0 F to 6^0 F increase in average temperature, 1- to 3-foot rise in sea level, or -15% to +15% change in average precipitation from historical levels by a certain point in the future). These ranges reflect factors such as discrepancies among models as well as the inherent uncertainty in future greenhouse gas emission pathways [76]. Managers may feel "safe" in considering the midpoint of those ranges (e.g., 4^0 F of warming, 2-foot rise in sea level, 0% change in precipitation) as the "more-likely" future for planning purposes; however, doing so is unwise, as it risks planning for an outcome that does not materialize and failing to anticipate conditions that may evolve [77]. Instead, all potential outcomes across the full range of projections are plausible and should be considered as equally possible.

Scenario planning supports decisions even when potential climate futures are divergent because it facilitates planning for the spectrum of possibilities [77]. For example, projections for the same geographical area may indicate generally increasing temperatures, with the possibility of either increases *or* decreases in average annual and/or seasonal precipitation. Managers engaged in restoration can increase their opportunities for success by choosing a mix of species that together have a wide range of tolerance for wet or dry conditions. Climate futures could also include plausible, but contrasting, extreme events. For instance, climate models may indicate potential for both more-severe flooding events due to heavier precipitation ***and*** an increase in the duration or intensity of droughts due to higher temperatures. In this case, it is necessary to consider the consequences of both possibilities, such as when developing stormwater infrastructure or water resource management plans.

Where directional trends are consistent (i.e., climate projections indicate trends in only one direction), it can be useful to consider least-change and most-change values (e.g., slightly warmer or significantly hotter; a few inches of sea-level rise or several feet of sea-level rise) over a given period. When projected changes are characterized by a high degree of confidence (e.g., generally higher sea levels), they might be considered as "predetermined elements" and included under *each* climate future.

Additionally, in some cases it is helpful to define meaningful ***threshold*** values for the relevant drivers when these are known (e.g., a temperature above which a species may no longer survive or a stage of sea level at which coastal infrastructure would be fully inundated) to help inform management actions [20, 61]. For example, while a 2^0 F increase in Maximum Weekly Average Temperatures may be insignificant in a stream where bull trout are comfortably within their range of tolerance, a similar increase in a stream already near its upper thermal limit could render conditions no longer suitable for the species [78]. Associated management strategies might involve continuing current approaches and monitoring stream temperatures to determine whether or when they reach a certain predetermined level (e.g., a few degrees below the threshold). If this "trigger point" is reached, managers might decide to implement additional or alternative actions (e.g., releasing cold water from nearby reservoirs or relocating fish to areas of cold water refugia) [79].

Assess Climate Vulnerabilities and Risks

After defining plausible climate futures, the next step is to determine their implications for the resources or infrastructure that are the focus of the plan. This is a crucial step, since understanding climate-related risks and vulnerabilities is the foundation for developing strategies capable of addressing those risks. Vulnerability assessments not only help managers identify *which* resources and assets may suffer climate-related impairment, they also help reveal *why*, *where*, and *when* they are vulnerable. Thus, understanding the basis for vulnerability serves to inform development of adaptation responses designed specifically to address those vulnerabilities (Step 4).

Assess Vulnerabilities under Each Climate Future

Numerous approaches and tools to assess climate change vulnerability are available, some of which are simpler and others more complex. The most-widespread method for vulnerability assessment involves a consideration of (1) the ***sensitivity*** of a resource or asset to a given change or climate impact; (2) the degree of ***exposure*** of the resource to that change; and (3) the ***adaptive capacity*** of the resource to cope with or adjust to the change or impact (see Box 5).

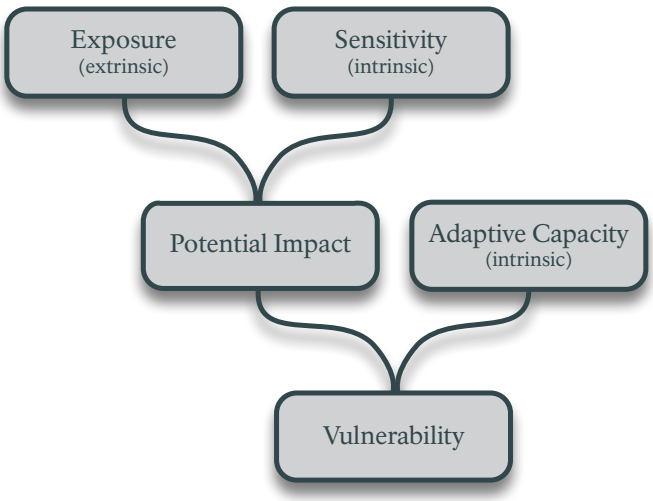


Figure 12. Three-part vulnerability framework. A depiction of the relationships between sensitivity, exposure, and adaptive capacity in defining climate vulnerability. Adapted from [59, 79].

The relationship among these three vulnerability components appears graphically (Figure 12), with the combination of sensitivity and exposure resulting in the potential impact on the resource, and adaptive capacity reflecting intrinsic capabilities of the resource or system to cope with or adjust to the changes. The concept of adaptive capacity does not apply to some resources, such as structures and other inanimate objects, that do not adapt on their own accord to better withstand changing environmental conditions. For these resources, it is sufficient to assess exposure and sensitivity.

Summarize Impacts or Vulnerabilities in Scenarios of Future Conditions

Scenarios used in subsequent steps in the adaptation planning process should capture the range of potential implications for management of the park's resources, assets, and values under the alternative climate futures, as identified through the impact/vulnerability assessment process. Scenarios may be described qualitatively (e.g., as bullet points or narratives) and/or quantitatively (e.g., via maps, tables, or graphs) reflecting changes under the alternative climate futures [86]. Appendix C provides examples of scenarios used in recent NPS scenario planning efforts.

Identify Highest Risks to Achieving Desired Outcomes under Each Scenario

Based on the identified vulnerabilities, it is important to identify those under each scenario that would have the greatest consequence for meeting the park's management goals. This step identifies key concerns from a management perspective. Identifying the most critical risks is key to developing appropriate adaptation responses.

It is important to realize that vulnerability assessment information does not dictate management response in that it may not be practicable in all cases to focus adaptation measures on highly vulnerable resources or assets. Depending on a park's mission and goals, it may be more appropriate to focus on maintaining or enhancing the condition of resources or assets that are less vulnerable, rather than attempting to maintain or restore assets that are clearly climate-compromised. Nonetheless, understanding the relative vulnerabilities of resources and assets provides the means to determine greatest risks and how those risks may play out over space and time.

BOX 5

UNDERSTANDING THE COMPONENTS OF VULNERABILITY (SOME EXAMPLES)

Sensitivity. Sensitivity is a measure of how and to what degree a park resource, asset, or value might be affected by climate-related changes. Sensitivity to climate change can reflect an intrinsic trait of a resource or asset, or it can be contingent on its condition. For example, historic structures made of wood are intrinsically more sensitive to climate-fueled wildfires than structures made of brick or stone. Similarly, coldwater-dependent species, like cutthroat trout, are more sensitive to changes in water temperature than fish with broad thermal tolerances, such as yellow perch. The condition or integrity of a resource or asset can increase or decrease its sensitivity. Healthy forests generally are less susceptible to climate-induced pest outbreaks than forests dominated by drought-stressed trees. In the same way, well-maintained infrastructure, such as historic buildings or roads and culverts, may be less sensitive to damage from extreme precipitation than unmaintained structures or deteriorating roadways with clogged drainage systems.

Exposure. While sensitivity may be an innate characteristic of a resource or asset, vulnerability also depends on the level of exposure to particular environmental changes. The term "exposure" means the nature and degree to which a system (object, etc.) is exposed to significant climate variations [75]. For instance, a temperature-sensitive plant may experience more exposure to climate-driven changes (thus be more vulnerable) at the southernmost boundary of its range or at lower elevations than at the northern boundary or at higher elevations. Evaluating the degree, magnitude, and pace of relevant changes (based on resource-specific sensitivities) can provide an estimate of potential impact or vulnerability. Alternative climate futures developed in Step 2 provide a basis to assess exposure.

Adaptive capacity. Adaptive capacity is broadly defined as the ability of a species, ecosystem, or human system[7] to cope with or adjust to changing climatic conditions [6]. Assessing adaptive capacity for species relies on an evaluation of several attributes, including distribution, movement, life history, demography, abiotic niche, ecological role, and evolutionary potential [81]. As an example, highly mobile species may have a greater capacity to track shifting climatic conditions than less mobile, or sessile, organisms. Components of habitat- or ecosystem-level adaptive capacity can include factors such as presence of natural or anthropogenic barriers to species dispersal, and redundancy and response diversity within functional groups [60]. Adaptive capacity is a challenging concept in vulnerability assessment and adaptation planning. For instance, some traits can be interpreted as either reducing sensitivity or increasing adaptive capacity. It is important to evaluate as many factors that affect climate vulnerability as possible to best inform management responses. To avoid confusion, some practitioners lump sensitivity and adaptive capacity together rather than grapple with subtle differences between the concepts [80].

7 Vulnerability assessments for human systems (e.g., urban areas, coastal communities) typically incorporate certain institutional factors (e.g., policy constraints, availability of funding) as elements of adaptive capacity [82, 83, 84]. Some parks have found it useful to consider such factors when assessing climate vulnerability (e.g., at Assateague National Seashore [85] and in the North Cascades [57]). For most parks, however, institutional concerns are likely to be more relevant in the evaluation and selection of adaptation strategies for implementation (Step 5).

Step 3: Evaluate Climate Implications for Management Goals

Building on the assessment of climate vulnerabilities and risks, Step 3 considers implications of future climatic conditions for achieving park management goals. Depending on the type, rate, and magnitude of projected changes, some current management goals may no longer be achievable. Others may remain viable and robust despite projected changes, while still others may be feasible only by implementing new management actions and approaches. Changing conditions may also create the need for new or additional goals, or different priorities to address emerging problems or concerns.

Step 3 thus entails reviewing current management goals to determine if climate change may wholly or partially affect the ability of the park to achieve the goals. If it is apparent that the goals cannot be met under projected future conditions, it is necessary to update or refine existing goals, or develop new, climate-informed goals.

Step 3 Key Concepts

- Management goals should be forward-looking, rather than retrospective, in light of rapidly changing conditions.
- Because some current goals may be climate-compromised and no longer achievable under future conditions, there may be a need to update, refine, or develop new goals.
- Goals increasingly should acknowledge continuous change and the potential for unavoidable losses or transformations.

Step 3 consists of the following activities:

- Assess continued feasibility of current goals
- Consider refinements or updates for climate-compromised goals

Assess Continued Feasibility of Current Goals

Evaluating how future changes in climatic and other ecological or social conditions may affect the ability to meet current goals is at the heart of Step 3. For example, a transportation planning goal that seeks to maintain year-round visitor access by personal vehicle along a frequently flooded road corridor may no longer be viable under exacerbated flood conditions projected for ongoing climate change. Assessing the viability of existing goals occurs in each of the scenarios developed in Step 2. Current goals will sort into three possible categories: (1) goals that continue to appear achievable under all scenarios, (2) goals that may be achievable (or partially so) under some scenarios but not others, and (3) goals that do not seem achievable under any of the scenarios. Those goals that fall into the second and third categories should be flagged as possible candidates for updates or replacement.

Consider Refinements or Updates for Climate-Compromised Goals

To manage parks most effectively under changing conditions, it is important that management goals specifically consider the implications of climate change. This step considers how to update goals that are partially or fully compromised under projected future conditions or develop new goals as warranted. Updates may not require wholesale goal revision, but rather modifications to just one or two of the following components: *what*, *why*, *where*, and *when*.

What (the subject of the plan: resources, assets, and values). In this context, *what* refers to the specific focus or emphasis of the management goal. In particular, it is useful to consider how the resources or assets are expected to fare under various scenarios of change and whether any unavoidable adverse effects or losses are expected or possible. Modifications to goals might be either within certain categories (e.g., shift from one species or historic site to another) or across categories (e.g., shift from an emphasis on maintaining certain infrastructure to enhancing surrounding habitat). For example:

- Climate projections at Apostle Islands National Seashore suggest that, under certain future conditions, the park may be able to support populations of the federally endangered Karner blue butterfly where it is not known historically. Managers have expressed interest in possible Karner relocation and efforts to facilitate emergence of barrens/savanna habitat in the park as an adaptation strategy for this endangered species [87]. This would be a new goal and new species for the park.

Why (why undertake this action, i.e., what are the intended outcomes of management decisions). Are the intended outcomes or desired conditions still relevant and feasible under the scenarios considered? Many current goals focus on restoration to historical conditions or persistence of current conditions. Do the specified "desired future conditions" align with what may be realistic under future climatic conditions? Although emphasis on persistence of a particular feature may continue to make sense in some instances, other situations may call for change-oriented alternatives. For example:

- Ecological thresholds have been documented in grasslands throughout arid and semiarid areas of the West, such as City of Rocks National Reserve in Idaho, where woody plants and invasive annual grasses have encroached into perennial grasslands and sagebrush steppe [88]. As climatic conditions and disturbance regimes exceed the historical range of variability, retaining those natural communities may no longer be achievable over time, thus requiring a change in goals that aim to retain native grassland and steppe communities.

Where (the relevant geography). Some goals are applicable parkwide, while others focus on specific geographic areas or management units. Given the differential impacts of climate change across the region and park, are there goals that remain relevant and achievable in some locations but not elsewhere? Modifications might be appropriate to specify a different area, or more clearly describe differing outcomes for different locations. For example:

- In the wake of extensive damage to a number of cultural resources due to Hurricane Sandy, and in anticipation of the increasing risks from sea-level rise and more-intense storms, managers at Gateway National Recreation Area have decided to refocus restoration and protection efforts toward structures in areas considered less vulnerable to climate change [89].

When (the relevant time frame or seasonality). Depending on the pace of climate-related changes, some goals may become compromised in the near term while others may remain relevant and achievable for decades. Climatic changes may also affect the applicability of season-specific goals (e.g., visitor services, operations and maintenance), as weather-related changes affect timing of visitation and increase or relax constraints on facilities and transportation networks. Are modifications necessary to distinguish among shorter-term and longer-term goals? Goals that are only feasible over shorter time frames (often thought of as "buying time" goals) are not necessarily inappropriate, but it may be prudent to identify indicators for potential tipping points beyond which those goals may no longer be achievable. It will also be important to consider the expected life span of the investment. For example:

- Planners at Everglades National Park considered the impacts of projected sea-level rise and exacerbated storm surges on facility and infrastructure investment decisions. As noted in the 2015 Final General Master Plan, "over the life of the plan (20-30 years), sea-level rise is not projected to be so severe that park facilities would become unusable, provided that new and replacement facilities continue to be planned and designed with climate change in mind" [90]. Implications of sea-level rise are likely to be different for decisions involving temporary or mobile structures, for instance, compared to permanent structures with a life span of 50+ years.

Table 3 provides examples of climate-informed goals as parks across the country consider climate change in developing and revising relevant management plans.

Table 3. Examples of climate-informed management goals in National Park Service plans.

Park Plan or Project	Goal	Comments
Acadia National Park Transportation Plan [91]	"Future transportation infrastructure design and construction is sustainable relative to sea-level rise, increasing storm intensities, and other climate-related future conditions."	The park is taking a long-term, climate-informed approach to making transportation infrastructure investments.
Christiansted National Historic Site (NHS) Wharf Bulkhead Replacement Project [92]	"The goal of the proposed action is to prevent damage from more frequent and more powerful seasonal hurricanes and to mitigate and remediate the effects of historic and continuing storm damage to the Christiansted NHS waterfront landscape, associated historic buildings, visitor use, and marine vessel operations."	The existing bulkhead was constructed with an expected life span of 25 years and was last refurbished in 1985. The proposed project would incorporate climate resiliency in the design, including a proposed life span of 40 years, to ensure that the resulting design is adaptable to anticipated future storm events with potentially greater storm intensities.
Devils Tower National Monument Resource Stewardship Strategy [93]	"Steward riparian woodlands through adaptive management planning that acknowledges changing conditions from climate change, altered river flow regime from upstream dam/reservoir management, and other stressors."	The park is embracing an adaptive management approach to natural and cultural resource stewardship in the face of a range of climate-related stressors.
Golden Gate National Recreation Area and Muir Woods National Monument Final General Management Plan [94]	"Connect visitors with resources through expanded and diverse science and stewardship programs that are focused on preservation and restoration of coastal and marine resources and address the implications of climate change."	The park has made climate change a front-and-center issue for visitors to help them learn about impacts and build support for solutions.
Sequoia and Kings Canyon National Parks Resource Stewardship Strategy [95]	"Wet meadows and fens are managed to minimize disruption of critical ecological functions during transition to different ecosystem types where self-sustaining wetlands are not likely to persist under changing climate."	The park recognizes the potential for a loss of wetland habitat under changing climatic conditions and is focusing on minimizing disruption to ecological functions in the interim.

Step 4: Identify Potential Adaptation Strategies

In general, ***adaptation strategies and actions*** should aim to reduce climate-related risks or provide benefits to the subject of the plan (resources and/or assets). It is important at this stage to think creatively about possible adaptation approaches and to not be overly constrained by tradition or past precedent; creativity, innovation, and "out of the box" thinking should be encouraged, since unprecedented challenges often require novel solutions.

This step describes a general approach for brainstorming and idea generation to identify potential adaptation strategies and responses. Where parks may have concerns about continued viability of current management strategies and/or new issues associated with climate change, it is important to ask the following questions:

- Under each scenario, what strategies and actions can reduce risks and enable the park to meet its goals?
- What strategies and actions can take advantage of possible opportunities presented by climate change?

Step 4 Key Concepts

- Adaptation strategies should explicitly link to climate-related vulnerabilities and risks.
- Possible adaptation responses may include existing, modified, or new strategies.
- The full array of adaptation strategies can include those designed to resist, accept, or even direct change.

Step 4 consists of the following activity:

- Identify an array of strategies to address important climate risks

Identify an Array of Strategies to Address Important Climate Risks

Developing climate adaptation strategies does not necessarily require generating new approaches from a blank slate. Current strategies may remain appropriate or can be modified to achieve current management goals, at least in the near term. Other situations may require both new strategies *and* updated goals.

Managing along the continuum of change, from persistence to transformation. As described in Section I, park management under changing climatic conditions may range from working to ensure persistence of historical or current states, to accepting change, to directing complete ecosystem transformation (for natural resources). For a particular natural or cultural resource or facility, such changes may relate to its location in a park or within the broader landscape, or its condition at a specific site. Changing climate regimes may pose a direct threat to the material integrity of historic structures, archeological sites, museum objects, ethnographic resources, and cultural landscape features. From a biodiversity/ecosystem perspective, change can apply to one or more system components, from species composition or vegetation structure, to ecosystem functions. Similarly, climate change may affect certain values that draw visitors to particular parks. Some changes may be subtle (e.g., changes in the timing of the river rafting season related to altered streamflow), while others might be transformative (e.g., lost ability of visitors to experience iconic or namesake species or historical/geographical features for which the park is known).

Adaptation actions may range from efforts to resist the impacts (e.g., erecting levees to protect structures from flooding, or retrofitting a building to withstand heavier rainfall or snowfall), to those that actively direct change to enable a park to achieve desired outcomes (e.g., creating new shrubland or grassland in an area that previously supported freshwater marsh). For many park resources and assets, managing for persistence might be a priority in the near term. Over time, however, efforts to resist climate-related changes will likely become increasingly risky and costly [29, 40]. For example, park managers may be compelled to accept changes, e.g. allow a barrier island to remain breached after a storm, such as at Fire Island National Seashore after Hurricane Sandy [96], or may work with partners to enhance habitat connectivity beyond park boundaries to allow for potential species movements, such as in the Greater Yellowstone Ecosystem [97]. Such options are likely to be most appropriate where impacts are infeasible to manage, where changes are insufficiently impactful to warrant a response, or where the expected outcomes are considered acceptable or even desirable.

Linking management actions to climate impacts. The most important element of this step is to explicitly link strategies and actions to the relevant climate impacts or risks being addressed. This is at the heart of intentionality, to ensure that management efforts are strategic rather than reflect "random acts of conservation," which may or may not be effective under changing climatic conditions. Accordingly, the planning record should include a brief section on *rationale and underlying assumptions* for the strategies described to meet management goals, including a description of how these can reduce risks to the subject of the plan (resources and/or assets) as well as any other benefits that those strategies may provide.

Examples of Adaptation Strategies and Actions

Many frameworks and approaches are available to help parks develop potential climate adaptation strategies and actions [7, 25, 32, 98, 99, 100]. Because of the wide array of park management responsibilities, specific strategies will vary.

Tables 4 through 7 provide examples of potential adaptation strategies and actions to address various climate impacts to natural or cultural resources, facilities, and visitor experience. These are hypothetical examples only; such actions would be determined in concert with planning processes through NEPA, the National Historic Preservation Act, and other guidance. Ultimately, park planners and managers will develop a suite of strategies and actions to meet specific needs given the park's goals, the nature of the impacts and vulnerabilities, and the decisions at hand in a particular park. It is important to (1) develop a wide range of potential adaptation responses, and (2) identify what each potential action broadly seeks to accomplish. Different adaptation approaches can be applied simultaneously to different elements of a landscape or park. One's approach may also shift (e.g., from resistance to acceptance) as climate change and associated impacts continue.

Table 4. Examples of climate adaptation strategies and actions for natural resources.

Natural Resource	Climate Impact	Desired or Achievable Future Condition	Strategy	Actions
Montane riparian wetland vegetation	Shifts in hydrology due to lower snowpack and earlier runoff leads to drier conditions and changes in riparian vegetation	Persistence of existing native wetland meadow	**Resist:** Maintain summertime water flows and actively manage vegetation	▫ Replace undersized culverts that constrain flows ▫ Restore beaver to watershed to increase water storage ▫ Reroute trails that alter water flows ▫ Remove encroaching woody species ▫ Interpret and communicate change to visitors and staff
		Conversion from wet meadow to woodland or shrubland	**Accept:** Allow eventual transformation from meadow to woodland or shrubland	▫ Remove damaged wetland vegetation, as necessary ▫ Interpret and communicate change to visitors and staff
		Conversion from wet meadow to grassland	**Direct:** Actively manage transition to grassland	▫ Conduct supplemental seeding with grassland species projected to thrive in emerging and projected conditions ▫ Implement prescribed fire to control woody encroachment ▫ Interpret and communicate change to visitors and staff

Table 5. Examples of climate adaptation strategies and actions for cultural resources.

Cultural Resource	Climate Impact	Desired or Achievable Future Condition	Strategy	Actions
Archeological site: shell midden	Potential damage/loss due to storm surge and sea-level rise	Persistence of the midden at/in its current site and condition	**Resist:** Prevent exposure to wave energy and flooding	▫ Build a living shoreline ▫ Build a sea wall ▫ Restrict boat access to reduce wave impacts ▫ Interpret and communicate change to visitors and staff
		Information captured from and about the site (artifacts and their context)	**Accept:** Allow for autonomous change, including loss of artifacts	▫ Document and photograph the resource to acknowledge its historical presence ▫ Interpret and communicate change to visitors and staff
		Artifacts are fully recovered from the site and archived	**Direct:** Proactively deconstruct site and relocate artifacts to *ex-situ* location	▫ Excavate the midden ▫ Recover and archive ▫ Interpret and communicate change to visitors and staff

Note: although this framework (resist, accept, direct) is optional and may not work well for non-living resources or the visitor experience, examples are provided here if useful to "stretch thinking" about adaptation options.

Table 6. Examples of climate adaptation strategies and actions for facilities/infrastructure.

Asset	Climate Impact	Desired or Achievable Future Condition	Strategy	Actions
Maintenance building	Increased severity of wildland fire due to higher temperatures and drought leads to greater risk of damage/loss	Existing facility remains intact and fire-safe	**Resist:** Minimize fire risk to structure	▫ Replace wood roof and siding with nonflammable materials ▫ Create/expand defensible zone around building ▫ Install automated sprinkler systems
		Facility remains intact as long as possible but acknowledge potential for damage or loss	**Accept:** Low priority for firefighting response	▫ Continue use until lost to fire
		New/relocated facility exists in safer location	**Direct:** Relocate existing building	▫ Identify lower-risk location

Note: although this framework (resist, accept, direct) is optional and may not work well for non-living resources or the visitor experience, examples are provided here if useful to "stretch thinking" about adaptation choices.

Table 7. Examples of climate adaptation strategies and actions for visitor experience.

Use or Experience	Climate Impact	Desired or Achievable Future Condition	Strategy	Actions
Peak-season activities (e.g., cross-country skiing in winter)	Shorter winters/ declines in snowpack limit skiing opportunities	Cross-country skiing remains viable, with no decline in visitation	**Resist:** Maintain snow conditions	▫ Install artificial snowmaking or strategically placed snow fencing ▫ Cover areas of trail overnight during warm spells to limit melting ▫ Interpret and communicate change to visitors and staff
		Cross-country skiing remains viable for as long as possible, but park also allows for alternative activities (e.g., hiking, biking)	**Accept:** Allow for alternative activities as conditions warrant	▫ Open trails to hiking/biking during periods of low snowpack ▫ Interpret and communicate change to visitors and staff
		Park no longer offers opportunities for cross-country skiing; shifts focus to biking	**Direct:** Redirect resources/staffing to development and management of biking opportunities	▫ Turn trails into dedicated mountain biking park (e.g., build ramps and banks that otherwise would not be tenable for skiing) ▫ Interpret and communicate change to visitors and staff

Note: although this framework (resist, accept, direct) is optional and may not work well for non-living resources or the visitor experience, examples are provided here if useful to "stretch thinking" about adaptation options.

Aligning goals and strategies. To summarize Steps 3 and 4, reviewing/revising goals and developing adaptation strategies is an iterative versus linear process. Figure 13 provides a frame to align management goals and strategies with climate change considerations. The *Business as Usual* frame describes a situation where a park pursues a current goal or goals using existing management strategies and actions. While this stage applies in cases where a park has not yet specifically considered climate change impacts, it might also be appropriate in instances where climate change is not expected to present significant challenges to meeting existing goals. *Climate Retrofit* represents a case in which a park determines that current goals remain viable under changing climatic conditions contingent on revised management strategies (e.g., conducting a management action at a different time of year). Under the *Climate Rebuild* frame, the effects of climate change are such that a park must update both current goals and management strategies.

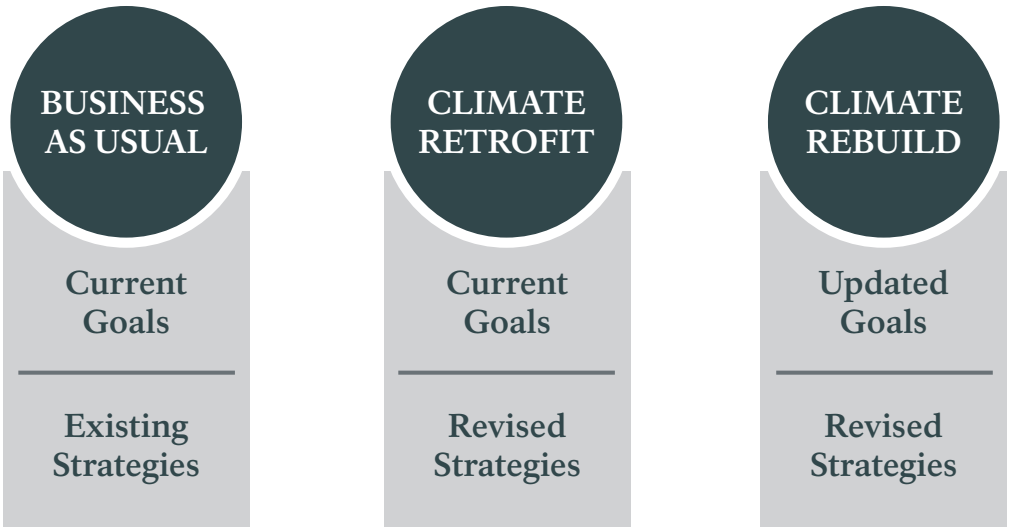


Figure 13. Aligning goals and strategies to achieve climate adaptation outcomes (adapted from *Climate-Smart Conservation* [7]).

Step 5: Evaluate and Select Priority Adaptation Strategies

The process of evaluating and selecting alternative adaptation strategies and actions relies on many planning best practices. With a few modifications to address climate change, existing evaluation approaches may be useful here, such as choosing by advantages [101], structured decision making, analyzing alternatives through a NEPA process, or others.

Step 5 Key Concepts

- Evaluate adaptation strategies for their performance against multiple scenarios and their ability to achieve climate-informed goals.
- Select near-term actions that are consistent with longer-term adaptation strategies, and do not limit future opportunities.
- Design major projects and investments to account for climatic conditions over the full project life cycle.

This step involves the following activities:

- Evaluate and compare promising adaptation strategies
  - Organize and cluster similar strategies and actions
  - Develop evaluation criteria
  - Evaluate strategies for effectiveness and feasibility
- Select priority adaptation strategies

Evaluate and Compare Promising Adaptation Strategies

Organize and Cluster Similar Strategies and Actions

Depending on the number of possible adaptation strategies and actions created in Step 4, the first element of Step 5 is to organize and cluster similar strategies and actions to facilitate managing the evaluation process.

Develop Evaluation Criteria

Determining evaluation criteria and assessing how well potential actions meet those criteria is a common step in most decision processes in the National Park Service. Regardless of whether the decision process is formal or informal, a transparent approach that documents assumptions and rationale is particularly important for managers to learn what actions best achieve goals, and practice adaptive management [28, 102, 103]. As part of a planning document or administrative record, "showing your work" will provide transparency to benefit others and assist evaluation of decisions.

Several general classes of criteria are relevant to evaluating and comparing alternative adaptation strategies and actions, or portfolios of actions. These are discussed below.

Park management goals. As a primary consideration, parks must assess how well the particular strategy/action helps achieve climate-informed management goals (from Step 3). However, it will not always be straightforward. In some cases, park managers may need to judge trade-offs among adaptation strategies and actions to achieve different goals. For instance, implementing certain actions, such as active fire management, may run counter to some goals of preserving wilderness character. Enhancing armoring to protect cultural resources or park facilities from more-intense storms and sea-level rise may negatively impact the park's coastal ecosystems. Managers should also be aware that the same intervention approach could serve different outcomes. For example, management techniques involving manipulation of genetic composition of communities (e.g., forests) may preserve the existing type of system, or it could be used to manage succession to a different type of system [104].

Other goals/values. How well does a strategy/action help achieve or hinder other (e.g., social, cultural, economic) goals, or provide co-benefits/co-costs to other sectors? Although these factors may not be the primary focus of park management efforts, assessing strategies in light of broader goals may identify possible synergies and trade-offs. For example, a project focused on choosing wetland restoration sites and approaches for fish and wildlife habitat might also provide flood protection to local communities. Conversely, a decision to abandon a historic site as it succumbs to rising sea levels could adversely affect the tourism economy of the nearby community. Taking time to identify the additional benefits/costs of various alternatives can be powerful in achieving broad consensus, or indicate where additional actions might be warranted to alleviate adverse impacts.

Effectiveness across scenarios. When future conditions are fairly certain (e.g., sea-level rise), it makes sense to prioritize actions to produce the best outcome given the expected future (i.e., optimal actions). When there is significant uncertainty about future conditions, however, it makes more sense to ask which actions give the best chance of some acceptable outcome no matter what scenario unfolds (i.e., which actions are robust)? In situations of high uncertainty, strategies that provide flexibility when conditions change or work across a larger number of scenarios may be more valuable than those that are effective in only one scenario.

On the other hand, in cases where uncertainty is high and a subset of the scenarios includes especially dire consequences (e.g., the destruction of an irreplaceable historic landmark, the extinction of an endangered species, or the complete loss of an ecosystem and its associated services), a park may decide to invest in actions to prepare for a "worst-case" scenario [59]. Although planning today for more-extreme future changes might cost more up front, preventive planning may reduce or eliminate more costly impacts down the road.

Park managers must also consider whether and how near-term actions are consistent with longer-term adaptation strategies to ensure that they do not limit future opportunities. In some instances, impacts may differ significantly between the scenarios, which may require planners to weigh trade-offs of various courses of action. For example, using natural or nature-based features (such as dunes) to protect coastal historical resources or park infrastructure might also enhance habitat for coastal birds and other species if project designs and maintenance plans incorporate best management practices for wildlife species. On the other hand, using structural armoring to protect cultural resources or facilities could come at the expense of surrounding habitat and visitor use opportunities by accelerating erosion.

Table 8. Example of a comparison table for evaluating strategies against a set of defined criteria.

Criterion	Strategy A	Strategy B	Strategy C
Criterion 1	H	L	M
Criterion 2	M	M	H
Criterion 3	H	L	L
Criterion 4	M	L	M

Notes: H = high, M = medium, L = low. In this example, strategy A scores best and C worst against these criteria

Feasibility. Consideration of the feasibility of proposed strategies is not unique to climate adaptation. Common criteria for assessing feasibility include direct costs, opportunity costs, technical feasibility, institutional capacity, partnership opportunities, community acceptance, and consistency with existing laws and policy.

Parks should also consider the opportunity costs of delaying action versus implementing strategies today. For example, now might be the time to acquire easements or upland habitats adjacent to neighboring coastal parks if those lands are not at risk from rising sea levels. Otherwise, such areas may be lost to development or other land use changes, precluding feasibility to accommodate inland habitat migration.

Evaluate Strategies for Effectiveness and Feasibility

Simple tools, such as comparison tables or sticky notes on a white board, can help planners evaluate various adaptation strategies and actions against the chosen criteria and facilitate decisions about which strategies to choose. Such approaches could contain rankings or scores to determine how well certain strategies comply with the criteria (see Table 8) or include brief textual arguments and comments for each option based on effectiveness/desirability.

If strategies are not a matter of "either/or" (i.e., they are all intended for use), evaluations can help identify areas where certain management actions might improve adherence to important criteria. For example, if a management action has the potential to be ***maladaptive***, are there certain design features that could reduce that risk? If a project is costly in the short term, are there opportunity costs for inaction that might justify near-term investment?

Select Priority Adaptation Strategies

Comparison tables can illustrate whether one option outperforms all others or, more typically, where trade-offs lie between different objectives and criteria. Risk tolerance levels will inevitably influence decisions. Consequently, it is important to discuss risk tolerance around potential actions and outcomes while also considering the consequences of inaction.

Step 6: Implement Strategies; Track Effectiveness and Changing Conditions

In *Revisiting Leopold: Resource Stewardship in the National Parks*, the NPS Advisory Board stated: "The overarching goal of NPS resource management should be *to steward NPS resources for continuous change that is not yet fully understood, in order to preserve ecological integrity and cultural and historical authenticity, provide visitors with transformative experiences, and form the core of a national conservation land- and seascape*" (emphasis added) [30]. This forward-looking goal recognizes that climate change is ongoing, that climate adaptation is necessarily a continuous process, and that communicating about our actions with stakeholders and visitors is even more important. It also underscores the imperative of tracking climate and related conditions and ensuring that monitoring results inform management decisions. Monitoring and evaluating progress are often overlooked components of management activities but are particularly important for the relatively new practice of climate adaptation; results from monitoring can contribute substantially to improving both understanding and management decisions.

The National Park Service has well-established ***monitoring and evaluation*** programs, which are an important source of expertise and existing information. Activities that build on existing monitoring protocols and data management infrastructure will likely be more efficient, less expensive, and more frequently successful. The design and execution of a rigorous, statistically valid monitoring design generally requires consultation with subject area experts, park staff, and possibly others who can assist with design, data management, and reporting.

As with any other monitoring purpose, monitoring the results of adaptation actions requires clear, specific monitoring goals. This bears special emphasis in the context of climatic changes that may complicate design and analysis of monitoring and evaluation. In this section, we discuss only those aspects most relevant to climate adaptation. Climate adaptation is an emerging field, and every adaptation action is an opportunity to learn. In the case of adaptation, monitoring and evaluation will focus on measuring performance, evaluating impacts, and determining what future conditions are emerging.

Step 6 Key Concepts

- Climate adaptation includes evaluating implementation, effectiveness, and continuously changing conditions.
- Monitoring indicators are essential to reduce uncertainty about future climates and resulting conditions.
- Adaptation is "learning by doing" and reporting is essential to improve park management.

This step entails the following activities and questions:

- Implement priority adaptation strategies
- Evaluate the implementation of priority adaptation strategies and actions. Are you doing what you said you would?
- Evaluate the effectiveness of adaptation strategies and actions. Are you achieving the desired outcomes?
- Monitor conditions to assess how the future is emerging. Are environmental conditions and resources changing as you thought they would?
- Document outcomes and adjust actions and plans as needed. What did you learn that can improve understanding and management practices?

Implement Priority Adaptation Strategies

Implementing climate adaptation strategies and actions is similar to other park management efforts and therefore can build on existing best practices. Working with diverse partners, proactively engaging stakeholders and visitors, and communicating success will foster successful implementation [7].

Work with diverse partners. Opportunities for cross-sector project implementation and cost-sharing should be fully explored. Partnerships are also particularly important in adaptation because success often depends on coordinated action at a broader landscape scale.

Engage proactively with stakeholders and visitors. Adaptation actions may look different from what stakeholders and visitors are accustomed to seeing and thus present both an imperative to communicate and an opportunity to educate. In particular, park managers may find it necessary to explain their approach and reasoning for addressing both the near- and long-term impacts of climate change because the importance of such actions might not be initially apparent to stakeholders and visitors [105].

Communicate success. Communication about climate change science and the actions that we can take to address the challenge is an important pillar of the NPS *Climate Change Response Strategy* [5]. Thoughtful communications can effectively interpret both the meaning and significance of change as it occurs, as well as the rationale behind adaptation strategies, thus increasing public understanding of challenges posed by climate change, advancing public support for management response, and inviting public participation in solutions [106].

In much the same way as the National Park Service interprets prescribed burning as a "fire-wise" strategy, relevant adaptation actions should be interpreted as "climate-smart" management. To that end, parks are encouraged to tap the expertise of their interpretive, education, and public information personnel during the implementation of adaptation strategies.

Evaluate the Implementation of Priority Strategies and Actions

Measuring implementation evaluates whether management actions are truly making progress toward specific project goals and objectives.

Implementation progress can be measured by conduct of activities, completion of outputs, or, sometimes, proposed project outcomes. Because many climate adaptation actions are long term, reporting implementation performance can be particularly important to demonstrate that projects are on track to achieve longer-term results. Performance measurements usually do not compare the outcomes of actions (e.g., weed removal) to what would have happened in the absence of action, so they normally are not determining cause-and-effect.

If project goals and objectives are well formulated and clearly articulated, performance can often be evaluated from project ***indicators*** that are easily measured and documented. Example indicators for implementation include the following:

- Engaging stakeholders
- Completing reports on time
- Completing field activities (construction, prescribed burn, habitat modification, etc.)
- Conducting educational workshops

These indicators often rely on existing or readily obtained information and expert judgement, and they usually do not require complex designs or specialized experience. Implementation monitoring is thus often relatively quick, easy, and inexpensive, particularly when compared with other evaluations of climate adaptation.

Evaluate the Effectiveness of Adaptation Strategies and Actions

Effectiveness monitoring entails assessing causal relationships between project activities and consequences. In other words, are the actions achieving what you thought they would? For example, have protective measures for cultural resources reduced decay? Have habitat restoration actions improved habitats and results in population responses? Have drainage systems accommodated severe storms and prevented damage?

In the context of climate adaptation, effectiveness monitoring and evaluation must address particular challenges:

- Results of adaptation efforts may not be apparent for many years, sometimes decades.
- Climatic changes are ongoing and baseline conditions are thus continuously changing.
- There may be no analogous system for comparison (need for counterfactuals).
- Variation in climate models and projected impacts may exist.
- Desired climate-smart conservation outcomes may be poorly known or articulated.

Unlike traditional projects, the desired outcomes for adaptation action cannot be based on thinking about historical conditions, but they must be grounded in the context of a projected climate future, with projected climate effects and system responses. Additionally, the design of the impact assessment will ideally be well suited and robust to the full range of anticipated conditions or scenarios, which may include highly divergent future conditions.

Climate adaptation projects may be designed to prevent a negative consequence from occurring, requiring the use of a "counterfactual" to infer what may have happened if no action were taken.

For natural resources, there may be good opportunities to leverage the existing vital signs monitoring of the Inventory and Monitoring (I&M) Program. It is unlikely that the existing monitoring will meet precise project needs, but I&M networks have broad expertise, will likely be monitoring important variables or co-variates (e.g., plant cover, climate, hydrology), and have highly functioning data management capabilities. *Keeping It Wild 2* [107] provides a useful guide to monitoring wilderness resources and character.

A variety of references may be useful to evaluate changing conditions of cultural resources. Data on the condition of historic structures, archeological sites, ethnographic resources, and cultural landscapes is documented, monitored, and available in the Cultural Resources Inventory System (CRIS) (access to non-sensitive records in the CRIS database may be requested by contacting WASO or regional CRIS Coordinators). Data on museum collections is available from the Interior Collections Management System (ICMS). Treatment recommendations for historic structures and cultural landscapes can be found in Historic Structure Reports and Cultural Landscape Reports available in the IRMA/Data Store. Other evaluative information can be found in National Register of Historic Places (NRHP) nominations, National Historic Landmarks (NHL) designations, park-specific reports, and through State Historic Preservation Offices (SHPO) and Tribal Historic Preservation Offices (THPO). The NPS Vanishing Treasures Program (https://www.nps.gov/orgs/1022/index.htm) has an active program (in 2020) to evaluate climate vulnerability of cultural resources in western parks, and Vanishing Treasures is developing a web-based application including climate and other threats to cultural resources. The primary source of information for NPS facilities and infrastructure is the Facilities Management Software System (FMSS) database. This is a rich source of data, but FMSS is a complex database and most people will require assistance to acquire and interpret FMSS data (refer to https://mylearning.nps.gov/library-resources/fmss-desk-reference/).

Monitor Conditions to Assess How the Future is Emerging

"It's hard to make predictions, especially about the future" – (unknown)

For many areas, projections of climate and associated responses are highly variable. Precipitation may increase or decrease; storms may become more intense and frequent, or not; anticipated impacts to park resources may or may not occur. Scenarios developed through the planning process may help identify variables that are early indicators of conditions consequential to planning decisions. Example questions that might be important to identify indicators include the following:

- Is the distribution of a warm-adapted pest species approaching the park (e.g., wood-boring insects killed by low temperatures)?
- Is peak runoff increasingly earlier?
- Are roads and trails snow-free earlier in the year?
- Do fire indices indicate increasing fire risks?
- Is flooding increasingly common?
- Are temperatures increasing at a rate more consistent with a "hot" or "warm" scenario?

Most climate adaptation projects and scenarios will include drivers and responses that occur at a broad scale, and broad-scale data (especially environmental data) are increasingly available. For example, historical and future (modeled) climate data are readily available (especially for the conterminous United States), although special skills may be required to convert the raw data into actionable information. As an alternative, there are many climate, environmental, social, and economic indicators in use by established programs that may be used with relatively little effort. Established indicators have additional benefits: they have likely been vetted by scientific and public audiences, they will likely have undergone extensive review and evaluation, and the underlying rationale and properties of the indicator will hopefully be known.

Climate is highly consequential to parks, influencing management actions for natural and cultural resources, visitor experience, and infrastructure. Many of the same climate drivers are important to an extremely broad range of park resources and facilities, and every NPS I&M network has information on climate trends in their parks. Additionally, the National Climate Assessment, US Environmental Protection Agency, National Oceanic and Atmospheric Administration, US Geological Survey, and other agencies and organizations have developed indicators of climate and related factors (e.g., drought, water levels, snow, ice) that characterize changes in climate and other conditions, helping to validate which assumptions (or hypotheses) about future conditions are correct and which are not. The key for monitoring conditions is to focus on "early detection" indicators to inform decisions about which strategies are most effective, and when change in management actions is warranted.

Document Outcomes and Adjust Actions and Plans as Needed

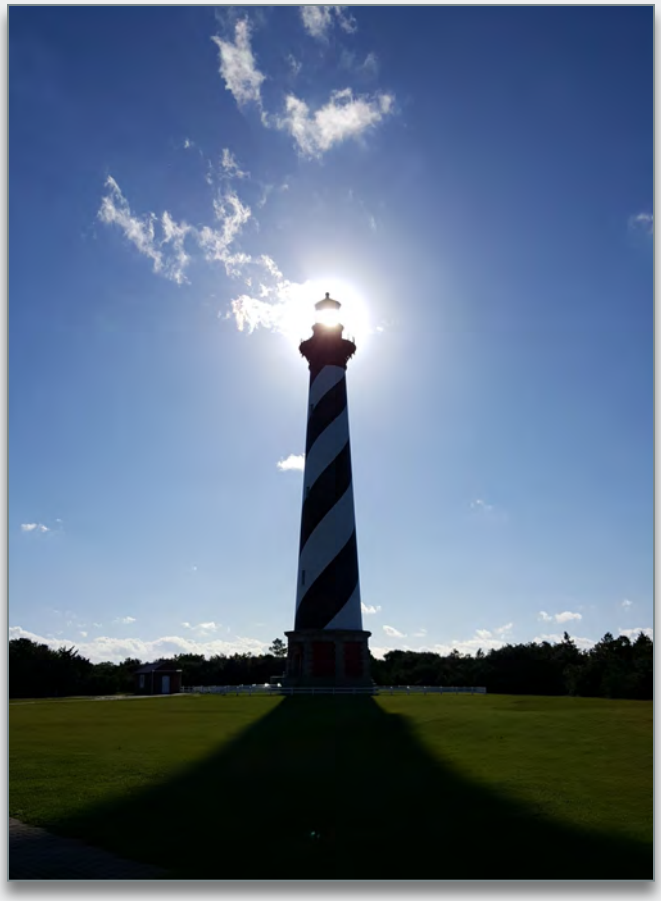
Our understanding of climate and climate adaptation is rapidly evolving. Learning by doing is the essence of adaptive management and underscores the need for active learning. With climate change, it is certain that the future for many parks will be very different than the present or past, although what that future will look like, how fast conditions will change, or what the path of change will mean are unknown.

As novel conditions emerge, the National Park Service can proactively plan for changing conditions and learn by documenting and reporting our management decisions and rationale to protect park resources and facilities, and our management actions and outcomes (both intended and unintended). Our resources are limited; documenting our "learning by doing" in every park can contribute to better understanding climate change, effects of climatic changes on park resources, and how best to manage parks for future generations.

Moving Forward

Management of America's national parks has always evolved as the National Park Service responds to advances in technology and scientific understanding of park resources, shifts in social norms and values, and changes in the statutory and regulatory environment. Conditions within and affecting national parks today are much different from those of past decades and will continue to change in the years and decades to come. With a vision toward the future, the National Park Service is well-positioned to incorporate climate adaptation in continuing to protect the special places and values of the national park system.

The principles and approaches described in this guide are intended to support park planners and managers in this new era of national park stewardship through an intentional and climate-informed approach, while considering the range of potential future conditions. Climate change is a significant factor that affects park ecosystems, resources, infrastructure, and visitor experiences. The National Park Service must understand and manage effects from a changing climate in order to protect park resources, just as we manage the impacts of invasive species, erosion, or wildland fire. Accounting for climate change in park planning and decisions helps ensure that public funds are used wisely, risks and hazards are minimized, and visitors will have enjoyable and safe experiences.



SECTION THREE

REFERENCE MATERIALS

Glossary[8]

Acceptance strategies. Management approaches involving purposefully taking no specific action to alter the trajectory of climate change effects on resources, assets, and values [108].

Adaptation strategies and actions. Adaptation strategies are the broadest level of adaptation efforts (i.e., resist, accept, or direct changes). Actions are the specific activities in support of an adaptation strategy (e.g., apply sandbags, install air conditioning, or translocate species to new areas). This guide uses the term "action" very generally and conceptually; it is not intended to trigger assessment or consultation requirements under either the National Environmental Policy Act or Section 106 of the National Historic Preservation Act.

Adaptive capacity. The ability to accommodate or cope with changing climatic conditions. Adaptive capacity is associated with intrinsic characteristics of the resource or asset (e.g., dispersal ability of species) and/or extrinsic factors (e.g., existence of natural or anthropogenic barriers to dispersal). The NPS considers that non-living resources (e.g. facilities, historic structures, archeological sites) have no inherent adaptive capacity in the way that living systems adjust to change, thus human management activities undertaken to reduce exposure and/or sensitivity of infrastructure or other non-living resources constitute adaptation actions.

Adaptive management. As defined in the U.S. Department of the Interior Technical Guide: "[a decision process that] promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood" [109].

Climate adaptation. "The process of adjustment to actual or expected climate and its effects in human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" [6]. Often also referred to as "climate change adaptation."

Climate projections. Descriptions of the future climate, typically from a quantitative model and based on specific assumptions and/or model parameters (e.g., greenhouse gas emissions). When a projection is branded "most likely," it becomes a forecast or prediction.

Climate drivers. Any climate-related factor (e.g., temperature, precipitation, sea-level rise, ocean acidification) that directly or indirectly affects or has the potential to affect a park's resources, assets, and values.

Climate-informed goals. Forward-looking goals that address new realities, challenges, and opportunities resulting from a shift in climate.

8 Definitions may be updated for consistency as the National Park Service develops additional planning guidance documents.

Continuous change. The concept that parks are not static entities, but instead are undergoing long-term change. This change is not merely a constant or seasonal change, but also the dynamic nature of overlapping and accelerating changes occurring in and around parks [30].

Desired conditions. As referenced in the NPS *Management Policies 2006*: "A park's natural and cultural resource conditions that the NPS aspires to achieve and maintain over time, and the conditions necessary for visitors to understand, enjoy, and appreciate those resources. These conditions are identified through a park's planning process" [8].

Directed change strategies. Adaptation strategies that intentionally plan for and actively work to guide the trajectory of change, with a goal of achieving desired future conditions. Example actions may include actively shaping ecosystem structure or composition such that new conditions better withstand the effects of climate change, or proactively making compatible alterations to cultural landscapes (consistent with the *Secretary of the Interior's Standards*) while protecting character-defining features.

Exposure. The degree to which a park resource, asset, or value might be subjected or exposed to climate change and associated variables.

Forecasts. Forecasts are similar to predictions. They are projections of future conditions that are considered to be "most likely." A forecast is often obtained using deterministic models that enable a certain amount of confidence attached to projections.

Historic integrity. The authenticity of a property's historic identity, evidenced by the survival of physical characteristics that existed during the property's prehistoric or historic period [110].

Impacts (of climate change). The specific effects (positive, negative, or neutral) of a climate driver on a park's resources, assets, and values.

Indicators. A subset of monitoring attributes that are particularly information-rich such that their values can be used to determine certain attributes of the focal system. For climate adaptation, these may include quantitative or qualitative factors that signify changes in climate drivers; the condition (e.g., quality, health, integrity) of resources or assets in response to those changes; progress toward relevant management outcomes; and the performance of management actions.

Intentionality. The fact of being purposeful in considering and addressing climate impacts in park planning and management.

Maladaptive. Adaptation actions are considered maladaptive if, in meeting the needs of one system or sector, they increase the vulnerability of another. For example, erecting a seawall may provide protection from storm surge for a coastal building, but it also increases the risk of erosion for adjacent, unarmored property [111].

Management goals. The desired outcomes of a management decision. Ideally, a goal statement conveys the underlying purpose of an effort ("why") but does not specify the means (i.e., strategies and actions) to achieve the desired outcome ("how").

Monitoring and evaluation. A process that involves collection and analysis of repeated observations or measurements to evaluate changes in conditions and progress toward meeting a management objective.

Natural condition. As referenced in the NPS *Management Policies 2006*: "The condition of resources that would occur in the absence of human dominance over the landscape" [8].

Non-climate drivers. Other ecological or social factors (e.g., land and water use, invasive species, pollution) that directly or indirectly affect or have the potential to affect a park's resources, assets, and values. Climate and non-climate factors can have synergistic effects on one another.

Persistence. An outcome of an adaptation action that maintains current (or restored past) conditions of the resources or assets that are the subject of the planning process despite climate change and its effects.

Plausible future conditions. Future (climatic, ecological, social, etc.) conditions that are considered credible or realistic, without assigning probability or likelihood of occurring.

Predictions. Forecasts of what will happen in the future with some degree of certainty or assigned probability.

Resilience. Definitions of resilience in the context of climate adaptation range from (1) the ability of a social or ecological system to maintain or return to a particular state following a climate-related disturbance or stress [112, 113], to (2) the capacity of a social or ecological system to adapt and reorganize to be better prepared for climate impacts [114].

Resistance strategies. A management strategy focused on helping a park resource, asset, or value withstand the impacts of climate change to remain within current acceptable conditions.

Resources, assets, and values. The natural and cultural resources, facilities, sites, landscapes, processes, visitor use values, and other features that are the focus of the particular planning or management effort. Typically, these will include Fundamental Resources and Values (FRVs) and Other Important Resources and Values (OIRVs) identified in a park foundation document, as well as facilities and infrastructure.

Risk. The probability and consequence of something being harmed by a climate change threat.

Robust strategies. Adaptation strategies that are likely to be effective across multiple scenarios.

Scenarios. Depictions of alternative futures that directly address the uncertain nature associated with a range of variables [21].

Scenario planning. A process for exploring plausible future change and how natural systems or humans might respond to those changes [21].

Sensitivity. A measure of how and to what degree a park resource, asset, or value might be affected by climate-related changes.

Shoulder seasons. Periods between peak and off-peak periods for park visitation.

Threshold. The point at which there is an abrupt change in an asset or resource value's function, structure, processes, or other important characteristics; also refers to situations in which small changes in an environmental driver produce large changes in the characteristic of the subject (which could be an ecosystem, a natural resource, a physical asset like a facility, a cultural resource, etc.)

Threat multiplier. Climate change and its impacts have the potential to exacerbate other threats associated with environmental, economic, social, and political factors.

Transformation. An outcome of climate change whereby the structural and functional conditions of a system are fundamentally altered.

Vulnerability. The extent to which a system is susceptible to and unable to cope with direct and indirect impacts of climate change.

Wilderness character. Although the Wilderness Act does not define "wilderness character," the interagency guide *Keeping It Wild 2* describes wilderness character as "the capacity of an area to elicit humility, to awaken a sense of relationship and interconnectedness with the community of life, and to evoke a feeling of restraint and obligation towards nature."

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Appendix A. Informational Resources and Tools

Scale of Information	Examples	Web Sources
Global, National, and Regional Assessments and Sources	Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (2014)	https://www.ipcc.ch/report/ar5/syr/
	Fourth US National Climate Assessment (2018) (includes both national and regional information)	https://nca2018.globalchange.gov/
	U.S. Department of the Interior (DOI) Climate Adaptation Science Centers (CASC)	https://casc.usgs.gov/centers
	National Oceanic and Atmospheric Administration (NOAA) Regional Integrated Science and Assessment Programs	https://cpo.noaa.gov/Meet-the-Divisions/Climate-and-Societal-Interactions/RISA/About-RISA#739083-risa-teams
	US Climate Resilience Toolkit	https://toolkit.climate.gov/
Resource-Specific Assessments and Sources	National Park Service (NPS) Data Store	https://irma.nps.gov/DataStore/
	NPS Sea-Level Rise and Storm Surge Maps	https://www.nps.gov/subjects/climatechange/stormsurgemaps.htm
	Federal Emergency Management Agency (FEMA) Flood Maps	https://msc.fema.gov/portal/search
	NPS Cultural Resources Climate Change Strategy	https://www.nps.gov/subjects/climatechange/upload/NPS-2016_Cultural-Resoures-Climate-Change-Strategy.pdf
	Climate Registry for the Assessment of Vulnerability	http://crave.cakex.org/
	NPS Coastal Hazards and Sea-Level Rise Asset Vulnerability Assessment Protocol	https://www.nps.gov/subjects/climatechange/vulnerabilityandadaptation.htm
	NPS Guidelines on Flood Adaptation for Rehabilitating Historic Buildings	https://www.nps.gov/tps/standards/rehabilitation/flood-adaptation-guidelines.pdf
Park-Specific Assessments and Sources	Park Visitation and Climate Change	https://www.nps.gov/subjects/climatechange/visitation.htm
	Assessment of Climate Exposure of 289 Park Units	http://www.nps.gov/subjects/climatechange/climateexposure.htm
	NPS Climate Change Response Resources	https://www.nps.gov/orgs/ccrp/index.htm
	NPS Climate Adaptation Resources	https://www.nps.gov/subjects/climatechange/adaptationresources.htm
Social Science-Related Information	NPS Park Visitation and Climate Change	https://www.nps.gov/subjects/climatechange/visitation.htm
	Yale Program on Climate Change Communication	http://climatecommunication.yale.edu/

Appendix B. Examples of Climate Drivers

The following table provides a sample (incomplete) list of climate drivers that are often considered important in determining the condition of resources/assets or guiding management actions. Final selection of key climate variables will generally require extensive consultation with park staff and a collaborator with the specific knowledge and experience necessary to acquire suitable climate data, conduct the analyses, and interpret and report the results. The NPS Climate Change Response Program can provide advice about selecting suitable climate drivers and, depending on requirements, conduct analyses or help locate suitable experts.

Temperature	Comments
Average temperature	Common reporting intervals are monthly, seasonal, annual.
Maximum temperature	Common reporting intervals are monthly, seasonal, annual.
Minimum temperature	Common reporting intervals are monthly, seasonal, annual.
Extreme cold: Coldest day of year	Historical data are more reliable than single-day projections.
Extreme hot: Warmest day of year	Historical data are more reliable than single-day projections.
Extreme hot days per year	Days that maximum temperature exceeds a threshold. Relevant thresholds vary geographically. Frequently 98th or 99th percentile.
Extreme cold days per year	Days that minimum temperature is below a threshold. Relevant thresholds vary geographically. Frequently 1st or 2nd percentile.
Freezing days per year	Days when minimum temperature is less than 0° C.
Hard freezing days per year	Days when minimum temperature is less than -2° C.
Freeze-thaw days	Number of days with a minimum temperature below 0° C and a maximum above 0°C.
Moist freeze-thaw cycles	Number of freeze-thaw days that include precipitation greater than a threshold (e.g., 1 mm).
Last frost	Annual Julian day of last frost before 1 July.
First frost date	Annual Julian day of first frost after 1 July.
Growing season	Variously defined; often period between last and first frost.
Growing degree days	Specified relative to a minimum temperature.
Heating/cooling degree days	Specified relative to cold/hot thresholds. Used to size HVAC systems.

Temperature	Comments
Longest hot event	Consecutive days with maximum temperature above a threshold.
Longest cold event	Consecutive days with minimum temperature below a threshold.
Extreme hot/cold daily temperatures	Average maximum/minimum temperature of the hottest/coldest 1% of days, annually, in a reference period.
Days above/below threshold	Thresholds are situation specific. Examples: low temperature required to kill bark beetles; high temperature that triggers fishing restrictions due to high stream water temperatures.

Precipitation / Humidity	Comments
Average precipitation	Sum of rain and water in snow (monthly, seasonal, annual, water year, or other period of interest).
Wet days	Annual/seasonal number of days with measurable precipitation (typically greater than 1 mm).
Snow days	Number of days with snowfall during period of interest (typically winter or a water year; usually NOT a calendar year).
Consecutive dry/wet days	Maximum annual number of consecutive days without/with measurable precipitation.
Extreme wet days	Annual (or seasonal) number of days when precipitation exceeds a threshold (often 25 mm or the 99th percentile of the historical period).
Annual snow fall	Average depth of total snowfall (typically over winter or water year, rather than calendar year).
Snow depth	At specific reference time; often 1 April.
Snow cover	Percent of area covered with snow. At a specific reference time, often 1 April.
Snow water equivalent (SWE)	Water content of snowpack measured at a specific time, often 1 April.
Climatic water deficit	Daily, monthly, seasonal, annual.
Average relative humidity	Daily, monthly, seasonal, annual.
Vapor pressure deficit	Daily, monthly, seasonal, annual.

Wind	Comments
Storm frequency	As appropriate to area. May be hurricanes greater than category rating, events that exceed a threshold wind speed, tornados, etc.
Strong or extreme wind	Days or events where wind exceeds a threshold speed.
Wind run	In kilometers or miles; usually reported daily.
Average wind speed	Usually a daily average.
Maximum wind gust speed	Greatest velocity of wind speed that exceeds 10 knots between peaks and lulls.
Wind direction	Direction from which wind originates (i.e. a southerly wind blows from south to north). Frequently reported as a wind rose showing wind speed and direction.

Sea-Level Rise	Comments
Sea-level rise	Increase over historical (reference) period.
Storm surge	Under specified condition (e.g., Category 3 hurricane).

Derived Indices and Variables	Comments
Fire risk	There are many fire risk indices. The Keetch-Bryam Drought Index (KBDI) is widely used and understood.
Extended spring index (SIx)	Estimated first leaf and first-bloom date.
Climatic water deficit	Daily, monthly, seasonal, annual.
Runoff	Many ways to measure and report.
Streamflow	Many ways to measure and report.
Drought	Often characterized by duration and intensity. Common measures are Palmer Drought Severity Index (PDSI) and standardized precipitation and evapotranspiration index (SPEI).
Heat index	A measure of how hot it feels to the human body when relative humidity is factored in with the air temperature.

Appendix C. Examples of National Park Service Adaptation Planning Scenarios

The following examples from recent NPS scenario planning efforts in parks illustrate a range of resources/management concerns and diversity of ways of expressing scenario implications.

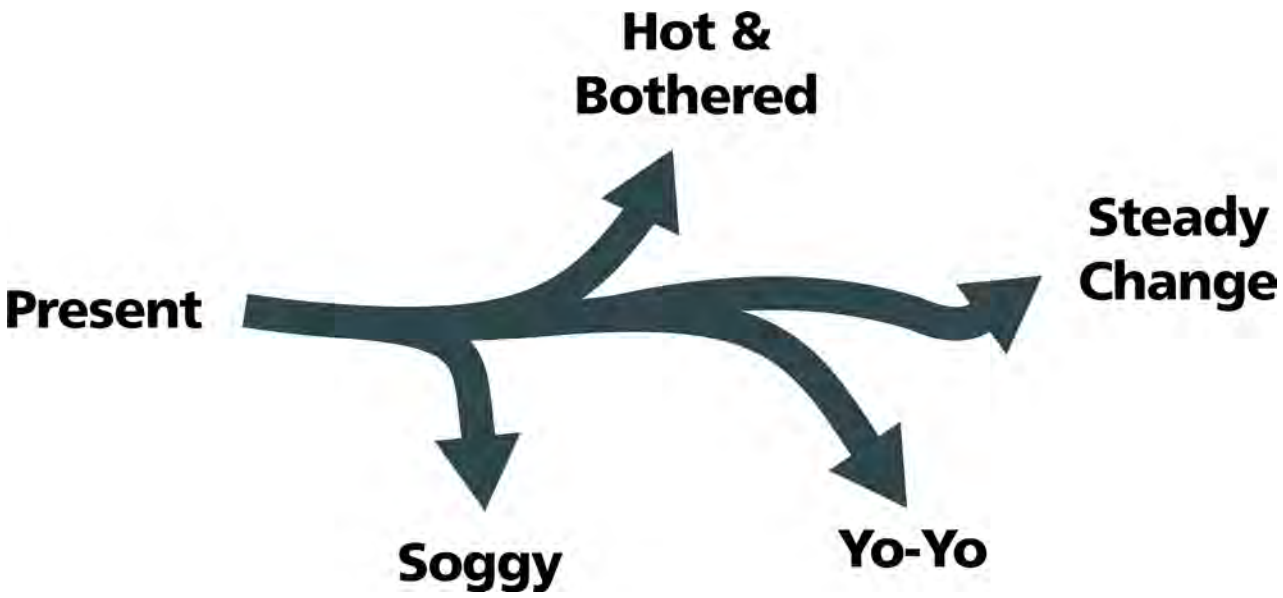
Example 1. Visitor implications under Devils Tower National Monument scenarios [93].

Developments and Resources	Spearfish	Still DETO	Blazin' Hot	Western Kansas
Visitors	▫ Wetter = more ticks and mosquitos, leading to worse visitor experience at times ▫ Wetter = increased disease risk with potential impacts on visitors (tularemia) ▫ Decreased climbing if wet? ▫ Increased fall visitation (longer season)	▫ Increased visitation due to longer warm season that doesn't get too hot compared to other scenarios ▫ More visitation hard to manage due to interannual variation in springtime arrival	▫ Shoulder seasons expand dramatically ▫ Peak-season visitation increases b/c peak-season temps still amenable ▫ More climbing in spring and fall; less in summer ▫ More heat-related illness ▫ Concern about visitor center capacity (i.e., more people might seek relief from the heat inside the visitor center)	▫ Shoulder seasons expand dramatically ▫ Peak-season visitation increases b/c peak season temps still amenable ▫ More climbing in spring and fall; less in summer ▫ More heat-related illness ▫ Concern about visitor center capacity (i.e., more people might seek relief from the heat inside the visitor center)

Example 2. Ecological implications under Acadia National Park scenarios [44].

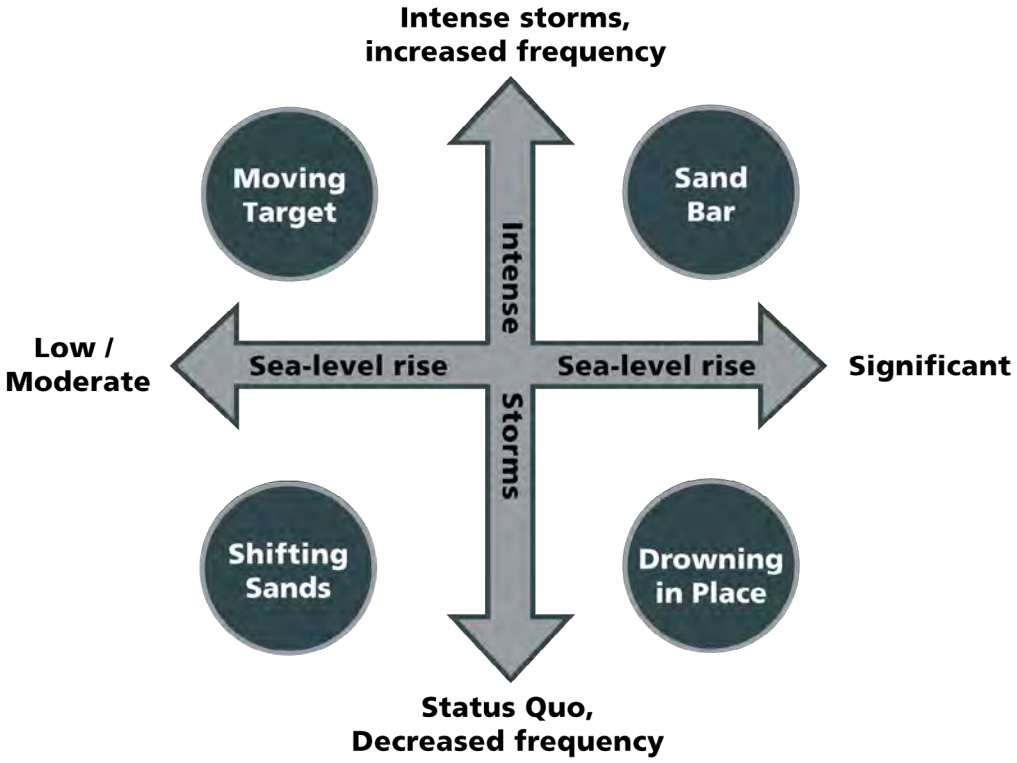
Focus	Calm Before the Warm	Sizzlin' Summer, Floodin' Fall	Bigger Boat
Ecosystem/ species dynamics	▫ Salt marshes will become drowned and migrate where they can ▫ Estuaries become more saline ▫ Coastal refuge for some species while it is colder than the rest of the country (early in scenario) ▫ Whole area becomes more susceptible to invasive species (late in scenario)	▫ Salt marshes increase where inland migration is possible; freshwater marshes decrease ▫ Increase in fire frequency/intensity ▫ Shift in forest composition (high mortality of mature boreal trees and recruitment failure) ▫ Immigration of invasive exotics/ diseases from southern areas coupled with heightened vegetative stress/ sensitivity to pests and diseases ▫ Vernal pool breeding amphibians vulnerable	▫ Increased volume and velocity of runoff results in more erosion ▫ Increased sedimentation, nutrients, and pollutants in streams ▫ Increased windthrow ▫ Species impacts—more endangered species and seabird nesting islands affected by storms

Example 3. Key climate futures and Lake Superior implications under Apostle Islands National Lakeshore scenarios spanning 2016-2040 [87]. Variability in the Arctic Oscillation (AO) is an important driver in this area, expressed as positive phase (+AO), weak, or negative phase (-AO) in the table below.



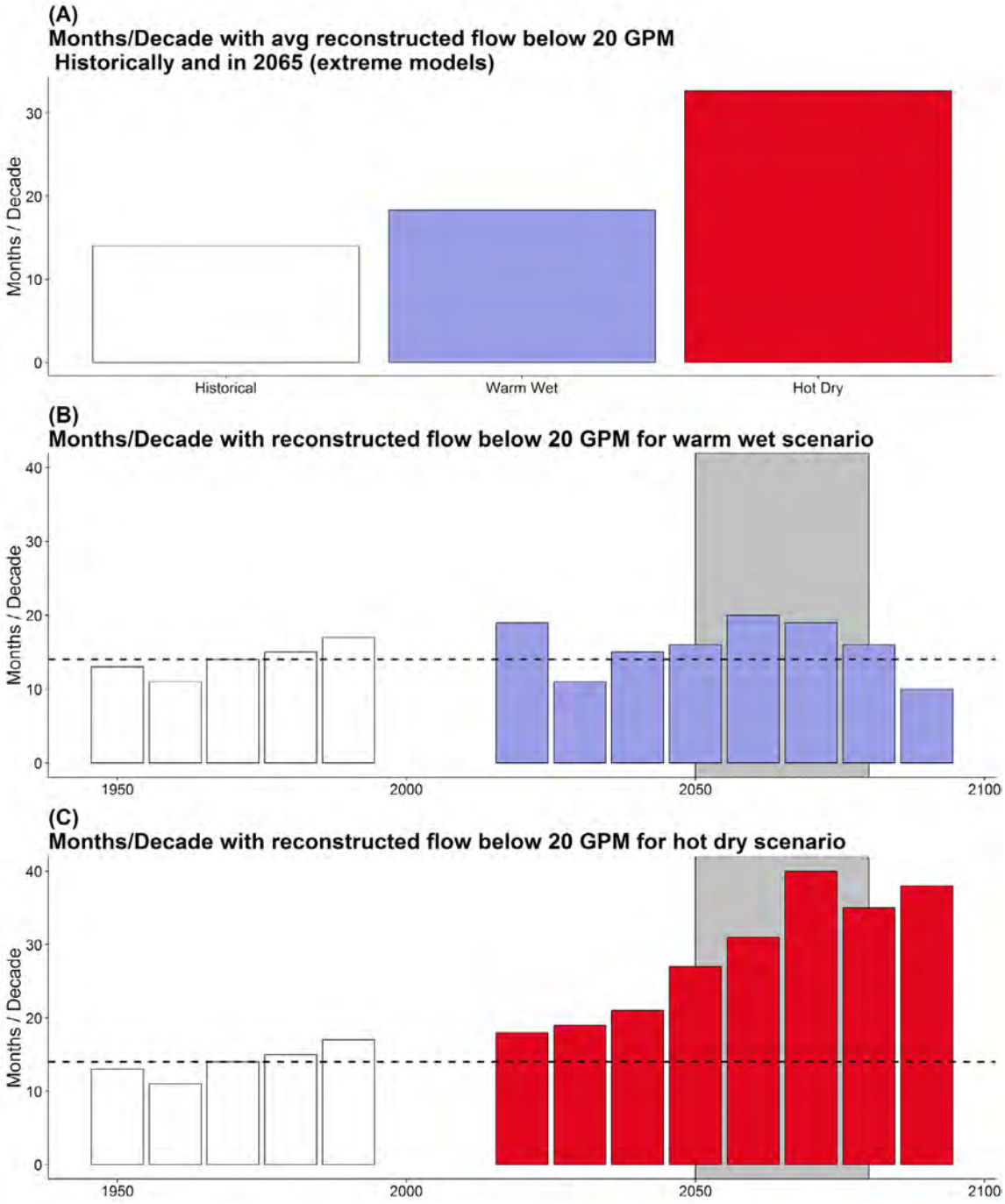
Hot & Bothered	Steady Change	Yo-Yo	Soggy
▫ Warm winters predominate (+AO) ▫ Hot and dry summer ▫ Stable lake ice extremely rare ▫ Lake level decreases ▫ Bothered: major disturbance complexes (wind and fire) hammer ecosystems	▫ Mild winters (weak AO) ▫ Warm summers, slight decrease in precipitation ▫ Stable lake ice infrequent ▫ Lake level decreases slightly	▫ Cool winters predominate (-AO) ▫ Hot and dry summers ▫ Stable lake ice forms periodically ▫ Lake level fluctuates greatly	▫ Cool winters predominate (-AO) ▫ Mild and moist summers ▫ Stable lake ice regularly forms ▫ Lake level increases

Example 4. Key climate futures and implications under Assateague Island National Seashore scenarios [115].



Moving Target	Sand Bar	Drowning in Place	Shifting Sands
▫ Episodic change (wave-driven washover) ▫ Higher productivity in the marshes ▫ Increased sediment from runoff ▫ Island size decreases; estuarine and marine area increases ▫ Dune erosion ▫ Simplified habitats ▫ Impacts on infrastructure	▫ Fragmentation; formation of multiple inlets ▫ Greater Potential for Breaching ▫ System unable to keep up with pace of change – from island to sandbar ▫ Habitats simplify, become uniform; less diverse ▫ Huge potential impacts to full range of communities (aquatic terrestrial, salt marshes)	▫ Loss of land mass from sea level rise; island exists "farther back" ▫ Individual storm events have big impact on resetting the landscape ▫ Recovery of system between extreme events is more likely ▫ Saltwater inundation and intrusion into freshwater aquifer ▫ Shift in types of plants (tolerance for saline environs, higher temperature, etc.)	▫ Dynamic; similar to today ▫ Expansion of complexity and stability of estuarine communities ▫ Lengthening of the growing season ▫ Some lowering of the water table with impacts on flora and fauna ▫ Migration of species northwards ▫ Greater risk of vector-borne diseases

Example 5. Oak Spring flow implications under Big Bend National Park scenarios [116].



Flows below 20 gpm are generally inadequate to support park operations in the Chisos developed area and may invoke a drought conservation plan. (A) Months per decade when the average flow is modeled to fall below the 20-gpm threshold under the Warm Wet (18 months) and Hot Dry (33 months) scenarios, relative to the 1950-2000 historical baseline period (14 months). (B-C) The number of months per decade when the modeled flow falls below the 20-gpm threshold through 2100 for the extreme models under the Warm Wet and Hot Dry scenarios. The dashed line is the historical average (14 months/decade). The period of interest for this study (2050-2080) is highlighted in gray.

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As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historic places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under US administration.

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